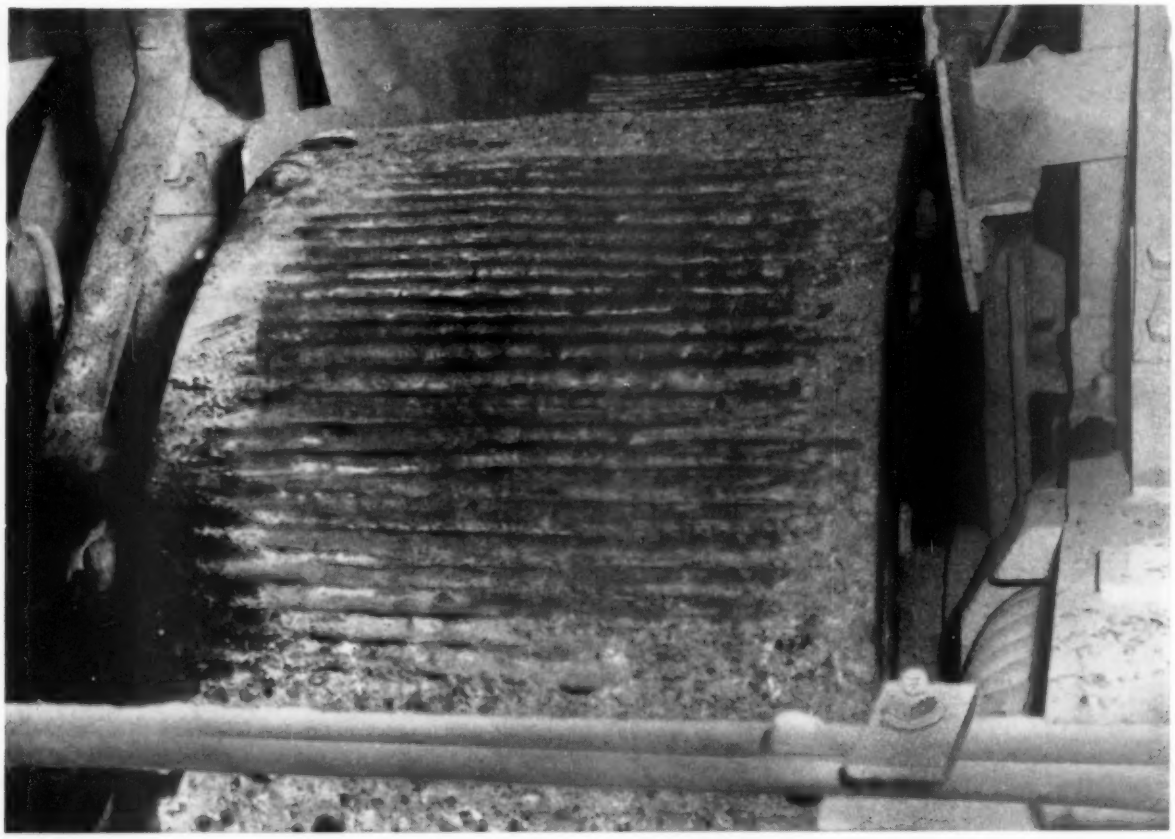
APRIL 1957

THE WELDING JOURNAL

IN THIS ISSUE

Automatic Welding Applications at an Oil Refinery 347
Control of Resistance Welding Machines 356
Inert-Gas Welding of Carbon-Steel Pipe 363
Arc Welding Titanium in Aircraft Applications 371
Stainless Steel for Welded Pressure Vessels 169-s
Strength of Brazed Joints in Copper Alloys 177-s
Properties of Metal-Arc Welded Ti-6% Al-4% V. 185-s
Upset Variables in Flash Welding of Steels 192-s
Table of Contents 343
Editorial 345
Index to Advertisers 448

OFFICIAL PUBLICATION OF THE AMERICAN WELDING SOCIETY



This roller, hardfaced with Victoralloy, shows practically no wear after crushing 40 tons of rock hourly, 8 hours daily for 30 days.

HOW TO SAVE ON ROLLERS AND ROD

....*Use VICTOR Hardfacing*

Tracy Rock & Gravel Co., Tracy, Calif., crushes 40 tons of rock hourly, prolongs roller life on this rough work by rebuilding with ¼" VICTORALLOY #1 Bare Electric rod, 28" length. Says plant superintendent Albert Parker:

> "Victoralloy's ease of application and fast buildup mean a lot to us. There is no lost time as we use 28" length rod; when it burns down, we touch a new rod to the old one, and keep on welding without even lifting the helmet."

You, too, can save rod and increase working life of crusher rolls, screens, shovel teeth, tractor rollers and idlers, dredge pumps and many other parts subjected to abrasion and severe impact. Simply hardface with VICTORALLOY. It welds to manganese, steel or cast iron. You get all position hardfacing, exceptional arc stability, deposits free of porosity, fast application without slag interference. Try it. Order a supply from your VICTOR dealer TODAY.

• FREE •

Victor Hardfacing Manual shows you right rod to use and how to apply it.

Write us NOW for your copy.

Profitable dealerships open; inquire now!

VICTOR for hardfacing

VICTOR EQUIPMENT COMPANY

ALLOY ROD AND METAL DIVISION

13808 E. Imperial Highway, Norwalk, Calif. • Wakita, Oklahoma

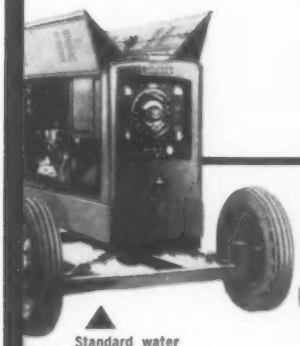
Setting "New Highs" in arc welded production

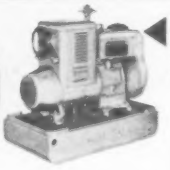
HOBART arc welders are reducing costs and boosting profits in plants everywhere

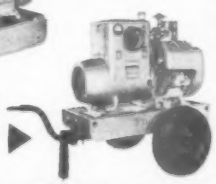
Extra built-in improvements and convenience features of the new Hobart arc welders now offer even greater speeds and an ease of handling that lets you boost production and lower your operating expense. You'll find a big difference when it comes to comparing welding equipment, so important to you in meeting today's rising production costs. Higher efficiency, extra power, extra capacity and the dependability you get in Hobart means better production facilities for cutting your costs. Don't delay any longer, get valuable information without obligation and see how Hobart welders can bring you added savings on your own work.

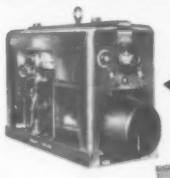
HOBART ELECTRODES are noted for their high quality. There's a Hobart electrode for every type of AC or DC welding. Let us know what type of work you do and we'll see that you get the opportunity of trying the proper electrode for your particular jobs. Extra speed, and uniform weld quality are what you can depend upon with Hobart Electrodes.

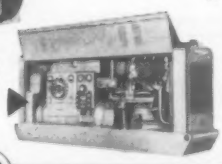
Hobart one of the world's largest builders of arc welding equipment

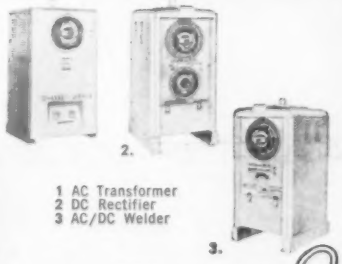

Standard water cooled Gas Engine Drive


Husky Boy 200 Amp. Air Cooled


AC Welder AC Power Combination air cooled


250 Amp. "Contractor's Special"


AC Welder AC Power Combination water cooled


1 AC Transformer
2 DC Rectifier
3 AC/DC Welder

HOBART TROY OHIO WELDERS

Get all the facts by simply filling in the coupon, or by writing us, stating any problem you might have on jobs you are contemplating. We'll be glad to send you helpful information.

HOBART BROTHERS COMPANY
Box WJ-47, Troy, Ohio, Phone FE-21223

HOBART BROTHERS CO., BOX WJ-47
TROY, OHIO

I'd like more information on _____ Amp. Arc Welder

☐ Elec. Motor Drive
☐ Water cooled
☐ AC Transformer

☐ Gas Engine Drive
☐ Gas Engine Drive with Auxiliary Power

☐ DC Rectifier
☐ Air cooled
☐ AC-DC Welder

Name _____

Address _____

City _____ State _____

☐ Send catalog on Arc Welding Electrodes.

nothing to stop you . . .

look — its sturdy, smooth, safely silver soldered tubes glide effortlessly through the operator's guiding hand. No obstructing coupling nut or tube joint hinders good performance, suggests the possibility of dangerous gas leaks. So many outstanding, modern and economy producing advantages have been incorporated into NATIONAL flame cutting torches that you, too, will find it to your interest and profit to write for the now rather famous brochure . . .

it's free, write today

"flame cutting—here's how it works"

it's made by

National of . . . california

536

NATIONAL welding equipment company... 218 fremont street san francisco 5 california

Pick Your Special Electrodes

From Hundreds of Existing MALLORY Designs

Need odd-shaped electrodes for resistance welding around corners, inside channels, or other out-of-the-ordinary places?

Before you go to the time and expense of ordering custom-made special electrodes, see what Mallory existing designs can do for your job. We have flexible tooling available for hundreds of different odd-shaped electrodes. What you consider a "special" may well be an existing Mallory type that you can get on prompt delivery . . . and at economical cost.

Included in the Mallory line are cold formed single bend and double bend types. Also, cast and forged offset designs. You have a wide choice of nose shapes, tapers and lengths. Bent electrodes are made by an exclusive Mallory cold-forming technique which develops maximum strength and hardness, to assure long life. Both single and double bend types can be supplied with fluted cooling holes and water tubes bent in place*, to assure highly efficient cooling right up to the welding face. All types use specialized alloys and manufacturing methods which Mallory has developed during thirty years of pioneering and leadership in the resistance welding field.

Stock Mallory straight electrodes, holders, seam welding wheels, dies, forgings and castings are listed in the latest edition of our Resistance Welding Catalog. Write today for this valuable reference book . . . and see your local Mallory welding distributor for prompt delivery of high quality welding supplies.

*Patent No. 2,489,993.

30 Years of Resistance Welding Leadership

In Canada, made and sold by Johnson Matthey and Mallory, Ltd. 110 Industry Street, Toronto 15, Ontario

Serving Industry with These Products:

Electromechanical—Resistors • Switches • Tuning Devices • Vibrators
Electrochemical—Capacitors • Rectifiers • Mercury Batteries
Metallurgical—Contacts • Special Metals and Ceramics • Welding Materials

Expect more . . . Get more from

P. R. MALLORY & CO. Inc.

MALLORY

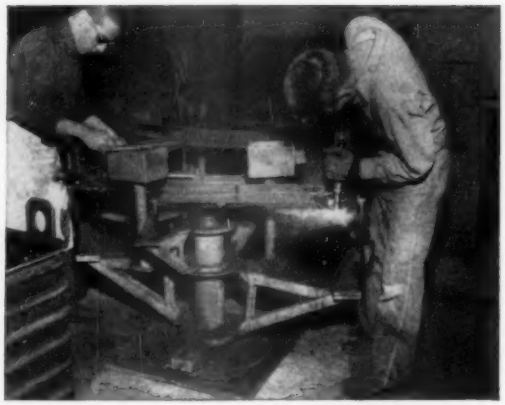
P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

For information on titanium developments, contact Mallory-Sharon Titanium Corp., Niles, Ohio

1

it's SIGMA SPOT-WELDED

2



School-desk standard assemblies are sigma spot-welded in a turn jig at the rate of 2 a minute.

3

In this highly efficient production setup, twelve clean, sound sigma spot-welds are made per steel desk standard in less than 15 seconds . . .

versatile and fast—Sigma spot-welding machines make top quality spot, plug, and tack welds on tubes, brackets, ducts, tanks, vehicle and machinery parts—and literally hundreds of other assemblies. Blanketed by a shield of inert argon gas, each weld is clean and sound requiring little or no weld finishing.

rugged and simple—Sigma spot-welding machines are ruggedly built for multi-shift production—and they are amazingly simple to operate and maintain. Get more information about the sigma spot-welding machine designed for your specific production needs. Call your local LINDE representative today, or write for free illustrated literature on sigma spot-welding.

Linde Air Products Company

A Division of Union Carbide and Carbon Corporation

30 East 42nd Street UCC New York 17, N. Y.

Offices in Other Principal Cities

In Canada: LINDE AIR PRODUCTS COMPANY

Division of Union Carbide Canada Limited, Toronto

The term "Linde" is a registered trade-mark of Union Carbide and Carbon Corporation.

Linde Trade-Mark

THE WELDING JOURNAL

VOLUME 36 • NUMBER 4 • APRIL 1957

TECHNICAL PAPERS, ITEMS AND REPORTS

Editorial—*Research—But One Step from Productivity, by Arthur R. Lytle* 345

Automatic Welding Applications at an Oil Refinery, by R. C. Wheeler and R. M. Kolb .. 347

A New Concept for Control of Resistance-Welding Machines, by W. J. Farrell and J. L. Solomon 356

The Application of Inert-Gas Tungsten-Arc Welding to Carbon-Steel Pipe, by F. J. Pilia and R. W. Minga 363

Design and Technique Requirements for Arc Welding Titanium in Aircraft Applications, by R. Meredith and B. L. Baird 371

PRACTICAL WELDER AND DESIGNER

Aluminum Replaces Steel in Lumber Rolls 378

Process Change Quadruples Welding Speed on Aluminum Pistons, by S. L. Sullivan and J. A. Gowen 379

Welded Truck Tank Prevents Liquid Propane Spillage 382

Heat Transfer and Corrosion Problems Solved with Sprayed Metals 382

All-Aluminum Shower Enclosures for Passenger Liners 384

SOCIETY AND RELATED EVENTS

Society News 386

Section News and Events 394

New Members 414

Current Welding Literature 418

News of the Industry 421

Personnel 432

Employment Service Bulletin 434

New Products 436

Abstracts of Current Patents 442

New Literature 444

Index to Advertisers 448

WELDING RESEARCH SUPPLEMENT

Stainless Steel for Welded Pressure Vessels, by A. Grodner 169-s

Strength of Brazed Joints in Copper Alloys, by W. H. Munse and J. S. Alagia 177-s

Investigation of the Mechanical Properties of Metal-Arc Welded Ti-6% Al-4% V, by D. M. Daley, Jr. and C. E. Hartbower 185-s

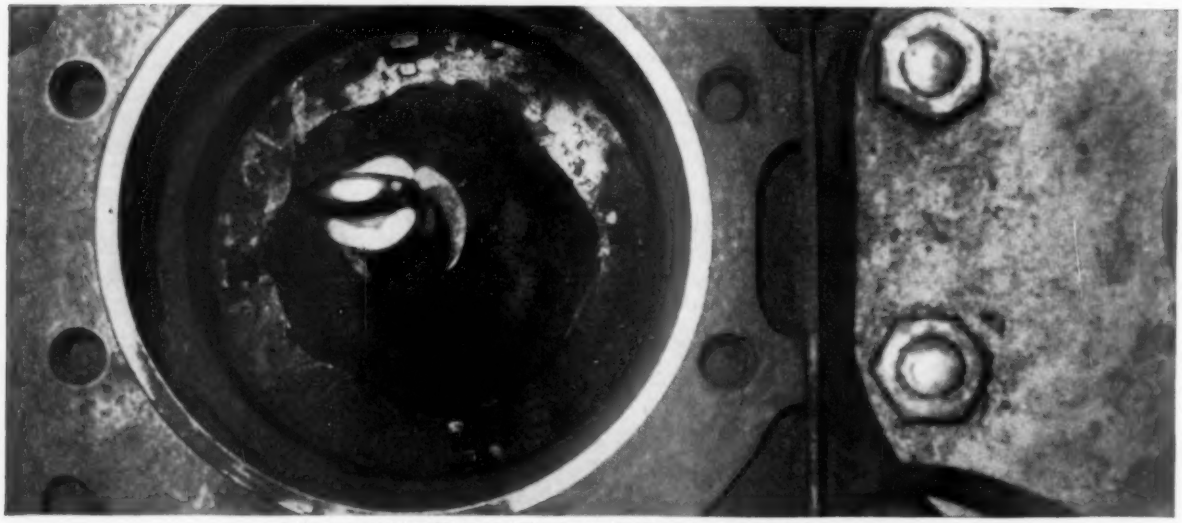
Research News 191-s

Studies of Upset Variables in the Flash Welding of Steels, by E. F. Nippes, W. F. Savage, G. Grotke and S. M. Robelotto 192-s

Published for the advancement of the science and art of welding by the American Welding Society

Published monthly by the American Welding Society. Publication office, 20th and Northampton Streets, Easton, Pa. Editorial and general offices, 33 West 39th St., New York 18, N. Y. Subscriptions $7.00 per year in the United States and possessions; foreign countries $8.50. Single copies, nonmembers $1.00; members 75 cents. Entered as second-class matter January 5, 1932, at the Post Office at Easton, Pa., under the act of March 3, 1879. Copyright 1957, by the American Welding Society. The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication provided credit is given.

Welding cast iron cylinder blocks down in the cramped engine room of a tug is routine . . .



with easy-handling Ni-Rod "55" electrodes. Repair saves $9,600 per engine.

Salvages $10,000 engine blocks by welding with Ni-Rod "55"

Down in the engine room of a diesel tug, space might seem too cramped for major repairs. But with $10,000 engine blocks at stake, Marine Industries, Ltd., had to try.

Their problem: salt water coolant corrodes through the guide ring that seals off the cylinder sleeve. Result: a $10,000 engine block is ruined.

With a fleet of tugs and tankers to maintain, Marine Industries searched for a way to repair these rings. Four years ago they found the answer:

Rebuild a corroded ring by welding with Ni-Rod "55"* electrode.

They found that Ni-Rod "55" electrode produces the strong, sound welds they need. Easy to use, Ni-Rod "55" electrode permits them to weld with the cylinder block in place. And weld deposits can be machined readily.

To date, Marine Industries has salvaged 23 blocks — a saving of nearly a quarter of a million dollars!

Find out more about successful welding with Ni-Rod "55" electrode. "A Handy Guide to Welding Cast Irons" gives tips on preparation, welding techniques, getting maximum machinability, and more. This illustrated booklet is yours on request.

*Registered trademark

The International Nickel Company, Inc.
67 Wall Street New York 5, N. Y.

INCO TRADE MARK

Welding Products
Electrodes • Wires • Fluxes

THE
WELDING
JOURNAL

Editor
B. E. Rossi

Assistant Editor, Production
Catherine O'Leary

Officers of the Society

J. J. Chyle
President
C. P. Sander
1st Vice-President
G. O. Hoglund
2nd Vice-President
R. S. Donald
Treasurer
J. G. Magrath
Secretary
F. J. Mooney
Asst. Secretary
S. A. Greenberg
Technical Secretary

Welding Journal Committee

O. B. J. Fraser
Chairman
E. J. Tangerman
Vice-Chairman

H. R. Clauser
John Haydock
C. L. Helms
C. G. Herbruck
John McCracken
J. E. Norcross
A. G. Oehler
G. W. Place
A. V. Scherer

EDITORIAL

RESEARCH—BUT ONE STEP FROM PRODUCTIVITY

To most people research and productivity represent opposite ends of the route that a new idea, process or product must follow in its development from conception to final fulfillment. Actually, research and productivity are closer kin as research may be applied directly to production problems.

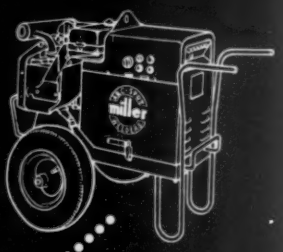
Research is not solely the study of fundamental principles. It embraces basic research on the underlying principles of the special science involved, studies on the application of general principles to actual problems, and on solving the engineering problems of materials and equipment. Thus, research has a new and broad meaning associated with the result and not the means and is directed to the better understanding of events and the general betterment of mankind. To fulfill these research objectives, it is necessary to develop and maintain large, expensive and well-staffed laboratories to provide a full range of technology and science in many related fields.

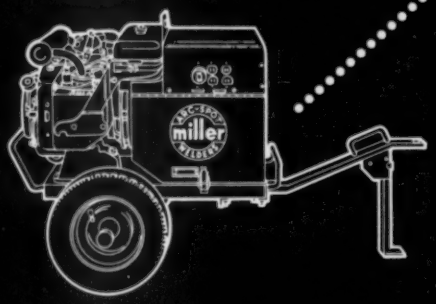
Two methods of research directed toward increasing productivity can be identified. Incremental research involves analyzing the process as now practiced, studying its indicated shortcomings and appraising all the factors that go into the process or the product. Welding filler metal composition control, the welding of alloy steels and brittle-fracture investigations were all aided by this method and the results have greatly aided productivity. The second method approaches the problem on a broad and uninhibited front: a broad basic program is set up and the researchers are relied upon to evolve the new process or product. With this procedure, it is not always clear what the answer will be because principles rather than processes are under study. This type of research led to many major advancements in production through the invention of submerged-arc welding, inert-gas-shielded arc welding and cutting, and other processes.

It is now impossible to anticipate what research holds in store, just as many years ago it was impossible to predict the present advanced state of welding. All our experience, however, convinces us that the upward curve of growth can be extrapolated along the same general slope as over the past decade or so. Therefore, we may anticipate great things for the future of production.

Arthur R. Lytle
VICE-PRESIDENT—RESEARCH
ELECTRO METALLURGICAL CO.

NEW!





Now equipped with a new and larger Onan 12.9 hp engine, the new Miller AEA-200-L produces a full 225 amperes of continuous rated, high cycle welding current or, 5 KW of 110/220 ac power for operation of power tools, lights, milking machines, etc., or, 1 KW of dc power.

Contractors, job weldors, farmers and many industries have shown a continuing high regard for the AEA's weatherproof ruggedness, easy portability and instant changeover versatility from ac-dc welder to power plant to pipe thawer.

Twin model, AEA-200, does not offer 110/200 power. Both welders may be equipped with rubber-tired running gear or road trailer.

Complete specifications sent on request.

". . . if it's Miller you know it's the finest . . ."

miller Electric Manufacturing Company, Inc. APPLETON, WISCONSIN

distributed in Canada by CANADIAN LIQUID AIR CO., LTD., Montreal

Fig. 1 Pipe installations such as this create need for field welding shop

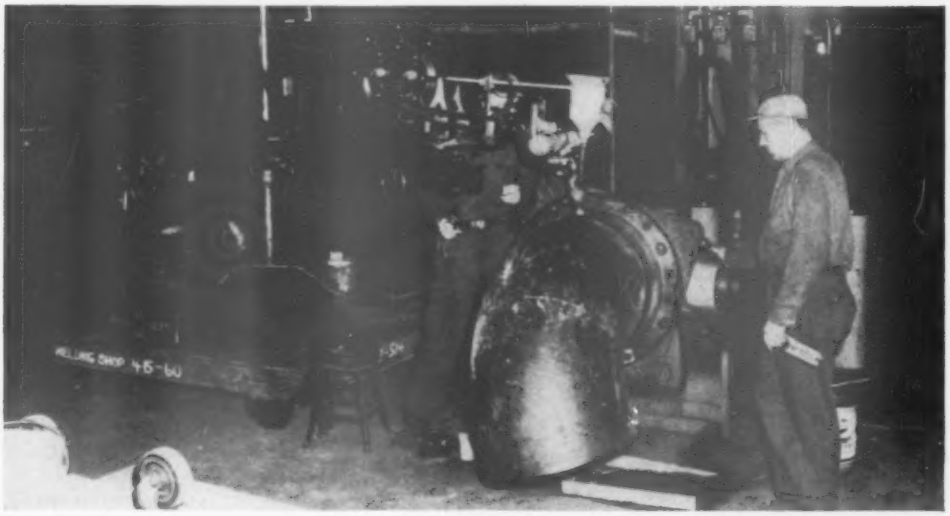


Fig. 2 Submerged-arc welder attaching a flange to an elbow

AUTOMATIC WELDING APPLICATIONS AT AN OIL REFINERY

Paper covers uses of submerged-arc and inert-gas metal-arc welding for pipe and boiler shop operation at the Whiting Refinery

BY R. C. WHEELER AND R. M. KOLB

R. C. Wheeler is Assistant Mechanical Div. Superintendent and **R. M. Kolb** is Zone Advisor, Mechanical Shops, Whiting Refinery of Standard Oil Co. (Indiana), Whiting, Ind.

Presented at 1956 AWS National Fall Meeting in Cleveland, Ohio, October 8–12.

Introduction

For many years, automatic welding was thought of primarily as a tool for production jobs. Today, through the proper application of positioning, handling and auxiliary equipment, production methods are effectively used for job shop and maintenance applications. Automatic welding offers neat-appearing, high-quality welds which can be made in a minimum of time with far less operator skill and fatigue than is needed for manual welding.

An automatic-welding process is defined as one

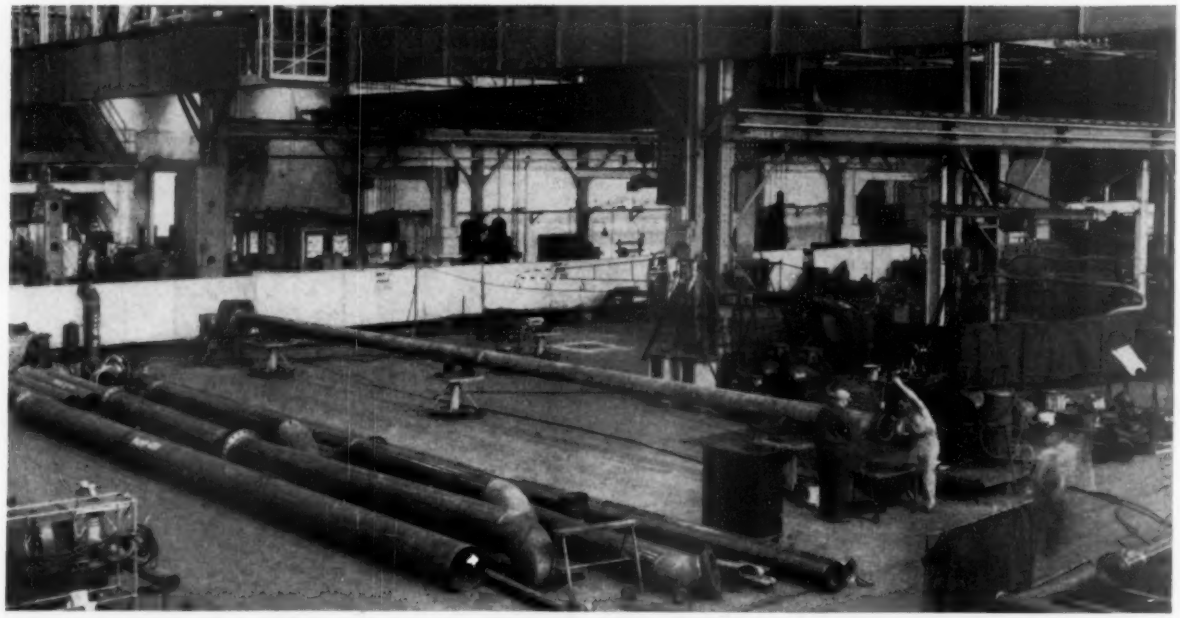


Fig. 3 Rotation of long length of 12-in. pipe supported on rubber-tired rollers by a face-plate type positioner during submerged-arc welding

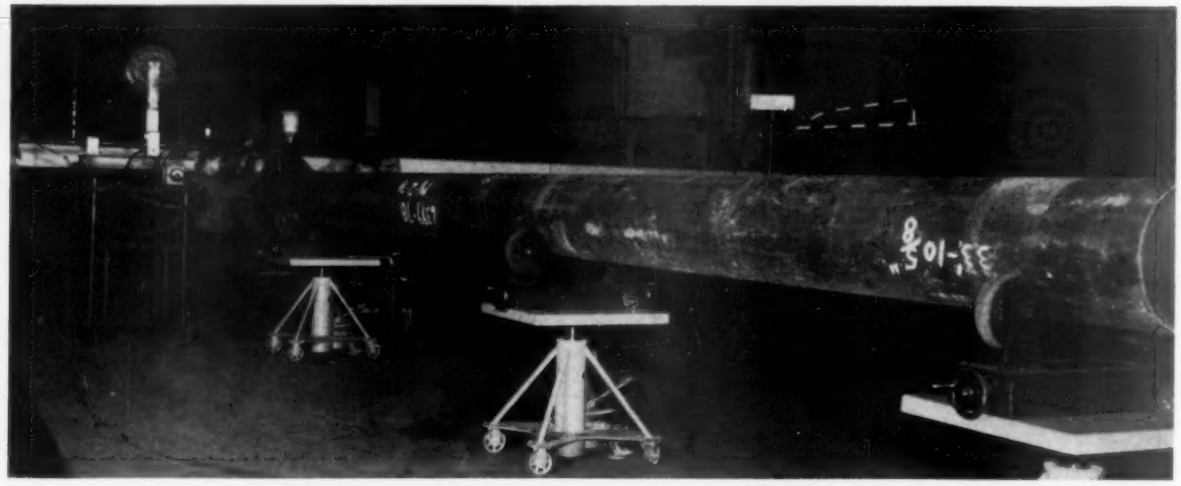


Fig. 4 Light-weight submerged-arc pipe-welding rig in operation on a long length of pipe

which performs the entire welding operation without constant observation and adjustment of the controls by an operator. In fully automatic welding, means must be provided to control the rate of advance or welding speed, while in a semiautomatic welding process the operator holds the welding gun in his hand and manually controls the rate of advance.

It is the purpose of this paper to discuss the application of submerged-arc and inert-gas metal-arc welding at the Whiting Refinery. The principal uses have been for pipe and boiler shop fabrication. These will be discussed, as well as a few repair applications.

Submerged-Arc Pipe Welding

Automatic welding of pipe is accomplished by rotating the joint beneath an automatic welding head. Figure 2 shows an elbow being joined with a flange by submerged-arc welding. In this process the welding takes place beneath a blanket of granular flux. It can only be used when gravity will hold the flux in place, or where suitable dams can be devised to retain the flux. It has been found both practical and economical to weld carbon steel and low alloy piping 6 in. and larger in diameter by this process. For smaller sizes of pipe, a poor appearing weld results because the curvature is too great to properly retain the flux and molten metal.

First Submerged-Arc Installation

Our first attempt at automatic welding was made in 1951 with the rig shown in Fig. 2. The submerged-

arc welding head was mounted on a boom and column type positioner. Movement of the boom up or down permitted vertical positioning of the head. In or out movement of the carriage, on which the head is mounted allowed transverse positioning. In addition, the boom could be rotated 360 deg on the column. The entire rig was mounted on a mobile base equipped with knuckle-type steering similar to that used on an automobile. This rig could be pulled to any location in the shop by two men and was effectively used to weld pipe and small pressure vessels.

Figure 3 shows the automatic welder in operation on a long straight length of pipe. The pipe is supported on rubber-tired rollers mounted on hydraulic lift tables. This arrangement permits the rapid leveling of pipe and centering it with the variable speed, face-plate type positioner used for rotation. This is a great time saver since a wide variety of pipe sizes are welded in our shops. In this setup, the flange weld closest to the positioner is made first, then the entire rig is pulled to the center of the assembly to make the next weld. In the location shown, the final flange weld is being made. The ground cable is attached to the frame of the positioner, rather than to the pipe, to prevent it from twisting. An extension of the positioner start-stop switch permits operation from the welding head location.

Long lengths of large-diameter pipe have been rotated by variable speed turning rolls. While powered turning rolls are very effective in welding large diameter pipe, they must be accurately aligned to prevent longitudinal creeping. For this reason, we prefer the type of rotating system shown in Fig. 3. By this arrangement, the end of the pipe is attached to a rotating positioner, and slight misalignments do not cause longitudinal creep. The positioner is not anchored to the floor.

Lightweight Submerged-Arc Rig for Pipe Welding

Submerged-arc welding of piping was very effective and, as the process proved itself, the work load was increased, until one machine was no longer adequate. It seemed advantageous to build a light, easy-to-move rig just for pipe work. Figure 4 shows the rig that was constructed for this purpose. It consists of an adjustable ram on which the automatic head is mounted. The ram is secured to an adjustable elevating table that rests on wheels. This rig can be rapidly moved from joint to joint on long piping. Foot-operated floor locks steady the table during welding.

Adjustable Pipe Support Rolls

The adjustable pipe support rolls shown in Fig. 4 were developed to permit the rapid changing of center distances between rolls. It is essentially a right- and left-hand screw assembly which adjusts each roll uniformly from the center as the handwheel at the side is turned. These are very valuable in our work, where pipe sizes from 6 to 24 in. are encountered frequently, and different roll spacing is essential.

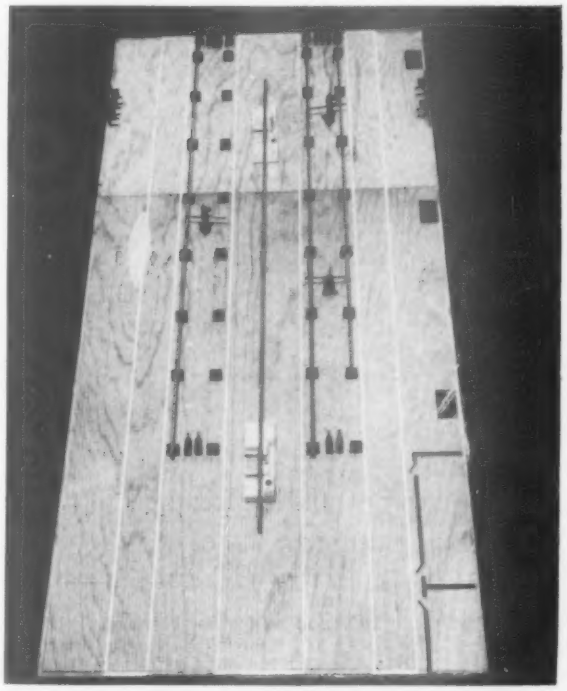


Fig. 5 Scale model showing floor layout in new 200 x 80 ft field welding shop

Flux Recovery Equipment

A portable flux trough is used to catch the surplus flux. This unit can be seen below the weld in Fig. 3. A 12-mesh screen at the top separates the large fused particles. The flux that passes through the screen into the hopper must be further processed to eliminate the "fines" and any rust particles. Failure to do so may cause weld porosity and blowholes.

We are currently using two different methods to accomplish this. One method involves a vacuum unit which sucks the flux from the flux trough to a vacuum tank. The "fines" are carried on through the tank while the usable flux drops out the bottom and flows across a magnetic separator which removes the rust.

In the other method, a mechanical vibrator is used to make the flux flow down an inclined plane across a magnetic separator and across a screen of proper mesh to pass the largest flux particles that can be reused. Flux passing through this screen is directed across a counterflow inclined plane made of such mesh that any particles too small for reuse will pass through it. Flux that does not pass through travels to a container for reuse.

Fire Creates Need for Field Pipe-Welding Shop

During the reconstruction period following the Whiting fire in August 1955, it was necessary to fabricate many miles of piping. Figure 1 shows one of the typical pipe installations. It consisted of two types of work: (1) long straight runs; (2) more complicated assemblies involving the use of weld ells and pipe bends for jump-arounds, take-offs or expansion bends.

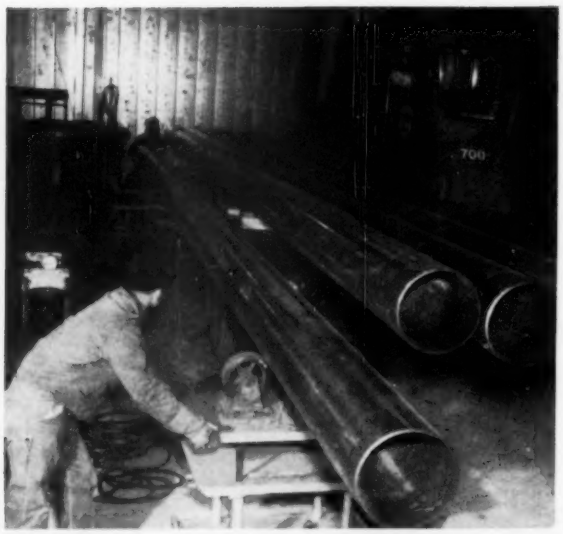


Fig. 6 Unloading the pipe on rubber-tired rolls mounted on elevating tables

Fig. 7 Tacking drive clip to plain end of pipe to permit rotation by face-plate positioner

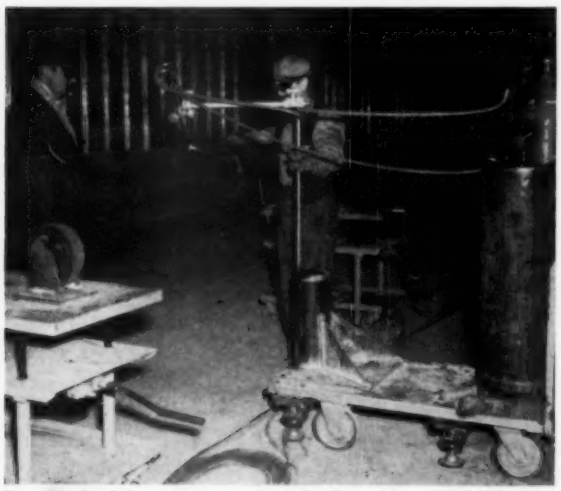


Fig. 8 Mobile oxygen-cutting rig for cutting and beveling pipe

To do this work in a minimum time, it was decided to erect a large steel building to be located on a new tank field site about two miles from our main weld shop. The plan was to join four double random lengths of pipe into a single length of approximately 180 ft. This permitted us to take full advantage of previous experience in automatic welding, and also to keep our field welds, which were to be made in winter weather, to a minimum.

Figure 5 shows a scale model of the new shop—a building 200 ft long by 80 ft wide, designed for bringing raw materials in at one end and finished piping out the other. There are four pipe fabricating lines consisting of face-plate type positioners, eight elevating tables equipped with rubber-tired rolls for each line, automatic submerged-arc welders, and eight motor-generator sets for manual welding. All handling was to be done by two-side-loading fork lift trucks that are shown carrying a length of pipe 160 ft long in this model.

Normally, the only pipe joints that are automatically welded are those that can be rotated under the welding head. In our previous shop operations, we followed the rather common practice of having fit-up crews tack the piping assemblies together prior to welding. To obtain the maximum number of roll welds, complicated assemblies had to be fitted up in several steps. In Fig. 2, a welding ell and a flange are being joined prior to being fitted into a more complicated assembly. Figure 3 shows numerous partial assemblies on the floor awaiting automatic welding. This system involves numerous materials handling operations back and forth from the fit-up tables. The welding foreman's job is also difficult, under this system, since he must maintain a "balance-wheel" of parts awaiting automatic welding to be sure the machine will not be idle. He must also know when all the subassemblies have been welded for scheduling final fit-up.

In the new shop we used two-man pipe fabricating crews. They were given all the necessary welding and

Fig. 9 Fitting flange to end of pipe

Fig. 10 Completing the weld by automatic submerged-arc welding

positioning equipment to carry a job to completion. The following paragraphs will tell how this system operated.

Pipe was properly stacked at one end of the shop so that it could be handled by a side-lift fork truck. Figure 6 shows four double random lengths of pipe that have been brought into the shop. They are being unloaded onto the rubber-tired rolls, which are mounted on elevating tables. The elevating tables have cast iron wheels and foot-operated floor locks. As shown here, they have been moved approximately five feet to the right from the center of the positioner, which can be seen in the background, to facilitate unloading. They are now ready to be pulled back in line with the positioner.

Usually there is a gap of several inches between pipe ends after unloading. By rotating the pipe with a chain tong the inherent misalignment of the pipe, with the rolls, will cause it to "walk" longitudinally. If the gap opens instead of closing, the pipe must be rotated in the opposite direction. By this means, the proper gap can be obtained very quickly. Chain tongs for large sizes of pipe are heavy and clumsy. It has been satisfactory to lengthen the chain on small, lightweight chain tongs for this work. Up and down changes can be made by adjusting the elevating tables. In and out changes, at 90 deg to the longitudinal axis, are made by pushing the tables on their caster-type wheels.

Figure 7 shows a method of rotating a plain-end pipe with a face-plate type positioner. A piece of 4-in. angle iron has been drilled and bolted into the adjustable slot in the positioner face. The other leg of the angle is tacked to the pipe. After welding, the angle is knocked off, and the broken tack weld is ground smooth.

Figure 8 shows a mobile oxygen-cutting rig, which was developed for cutting and beveling pipe. Actually, it is a hand push-cart equipped with a machine cutting torch mounted on a boom and column. The boom can be adjusted up and down on the column and moved in or out. The torch is mounted through an angle head so that the bevel angle can be set. Cuts are made by locating the torch over the cut-off line and rotating the pipe beneath it. Fortunately, the speed of rotation used for automatic welding can also be used for flame cutting, thus eliminating the need for readjusting the positioner speed.

Figure 9 shows a flange being fitted to the end of a long section of pipe. The flange is supported on an adjustable elevating table while it is aligned and tack welded.

It is our practice on noncritical piping to put in root passes by manual arc welding, prior to automatic welding. With two-man fabricating crews, two root passes are made simultaneously. On high-pressure high-temperature piping, the root pass is put in with inert-gas tungsten-arc welding using an inert-gas backing.

Figure 10 shows an automatic submerged-arc weld in progress. The operator keeps the electrode centered in the welding groove. We use a multipass technique where approximately three passes are used to complete a weld. The second man in this photo makes sure that all slag is removed. The rig being used here is a boom and column-type machine, mounted on wheels so that

Fig. 11 Completed 185 foot length of pipe leaving shop

Fig. 12 Long lengths being transported from shop to job site

it can be moved from joint to joint along the pipe. Table 1 gives the welding settings for the various sizes of pipe. Amperage settings on the first pass are limited in order to prevent burning through the manual root pass. Usually 330 amp is the proper setting, but if there is an exceptionally light root pass it must be reduced. After the first automatic pass is made, the current can be increased. On standard wall pipe there is little incentive to increase the amperage after the first pass since the weld is usually complete after three passes; however, on heavier-walled pipe, it is well to increase the current. It should be noted that the travel speed increases from 14 ipm for 6-in. pipe to 40 ipm for 24-in. pipe. Faster travel speeds on smaller pipe do not allow adequate time for the metal to solidify, and poor weld appearance results. We have installed tachometers on our face-plate type positioners so that the operator can set his travel speed quickly. Another factor which has a decided effect on weld appearance is the distance the electrode is backed off top dead-center. This is known as "offset," and it permits the weld to be made before it reaches top dead-center. This allows the molten metal more time to solidify by keep-

Table 1—Approximate Settings for Submerged-Arc Welding of Pipe Using $^{3}/_{32}$ In. Carbon Steel Electrode

Pipe size	*Welding speed, ipm*	*Offset,* in.*	*Amp*	*Volts*
6	14	$^{5}/_{8}$	330	30–35
8	18	$^{13}/_{16}$	330	30–35
10	18	1	330	30–35
12	20	$1^{3}/_{16}$	330	30–35
14	20	$1^{5}/_{16}$	330	30–35
16	25	$1^{1}/_{2}$	330	30–35
18	28	$1^{3}/_{4}$	330	30–35
20	30	$1^{15}/_{16}$	330	30–35
24	30	$2^{1}/_{4}$	330	30–35

* Offset may be set 11 deg off center instead of measuring in inches.

ing it on a portion of the pipe where the weld metal does not tend to flow excessively. This can either be done by measuring the distance off center, in inches, or by setting it at 11 deg, which is satisfactory for all sizes of pipe. After the operator becomes experienced, he can set this offset by eye, on pipe 10 in. and over, but it is quite critical on 6- and 8- in. pipe.

Figure 11 shows a length of pipe, approximately 185 ft long, being taken from the shop. Figure 12 shows several of these lengths being carried to the field installation site on a bolster truck and trailer.

While the new shop was intended primarily to fabricate long straight lengths of pipe, it proved very effective in fabricating three-dimensional piping assemblies as well. Two-man crews carried the jobs to completion, eliminating excessive materials handling, and keeping the foreman's work to a minimum as it eliminated the need for knowing the status of subassemblies. Figure 13 shows a three-dimensional assembly fabricated with a minimum of hand welds. The small pipe connecting the elbow to the positioner face is only a means of rotation for automatic welding. After welding, the tack welds were broken off and ground smooth. The use of elevating tables and the ability to rotate the header with the positioner greatly simplifies fit-up work. Figure 14 shows two ells, previously joined by automatic welding, being attached to the end of a long straight length of pipe. At this stage, the two-man fabricating crew is making the root pass prior to automatic welding. The elevating tables have been raised

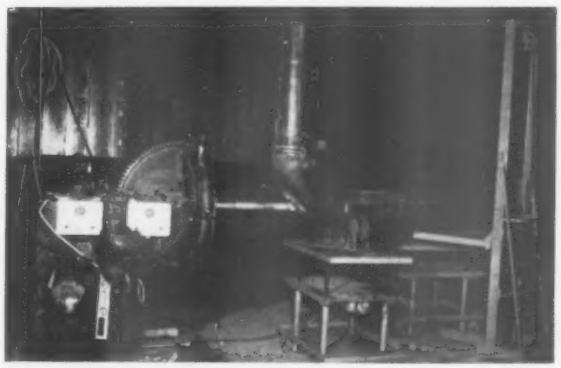


Fig. 13 Fabrication of three dimensional assembly with a minimum number of hand welds

Fig. 14 Joining elbows to end of long length of pipe

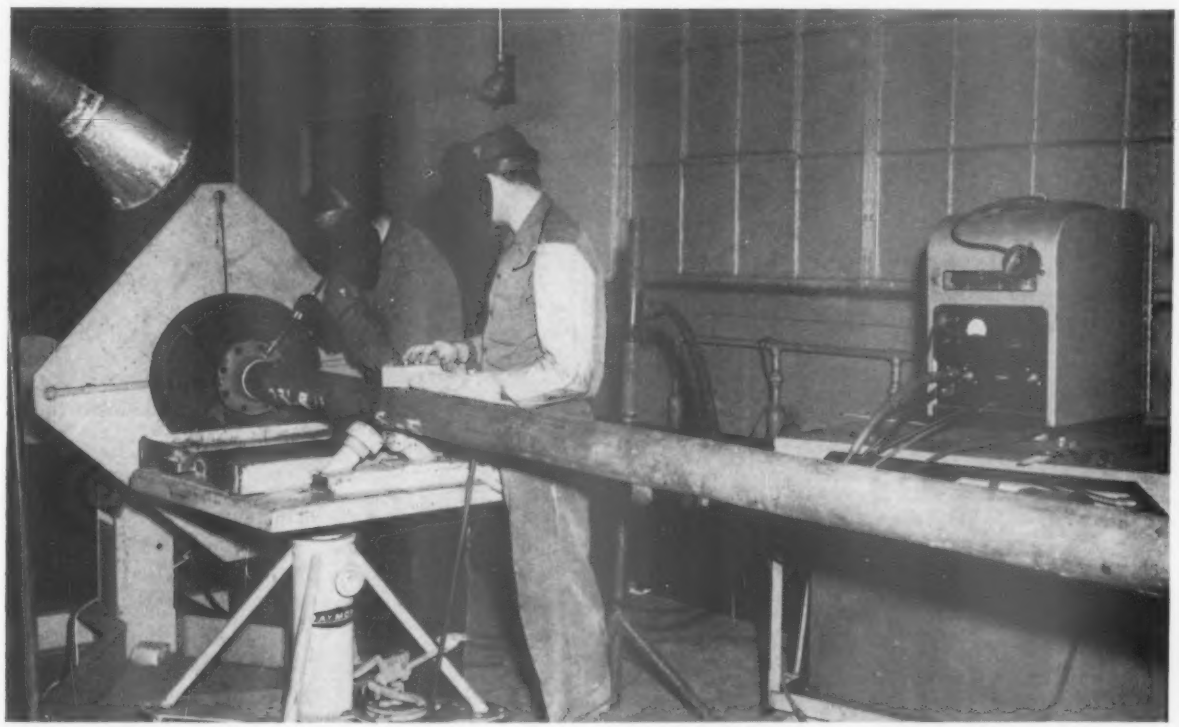


Fig. 15 Welding flange to brass pipe using inert-gas metal-arc welding

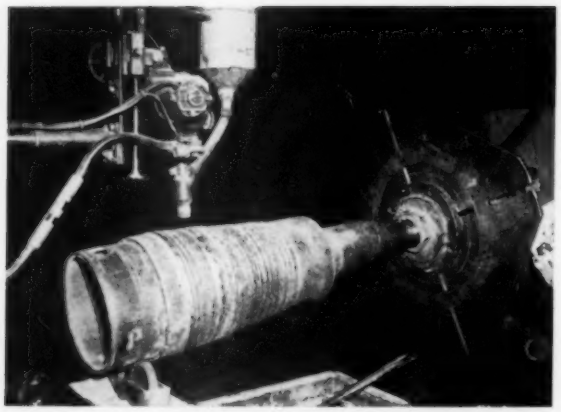


Fig. 16 Plug cock surfaced with Type 410 stainless steel by submerged-arc welding

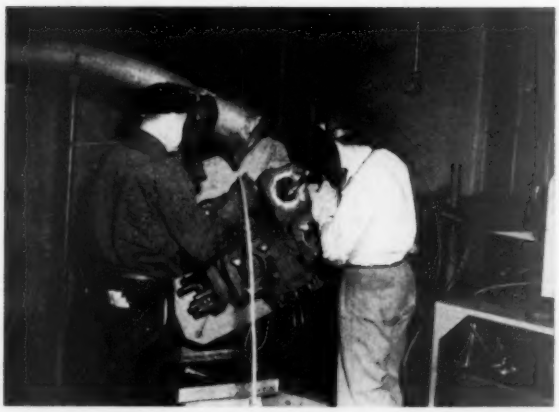


Fig. 17 Valve seat in brass pump being built up by inert-gas metal-arc welding

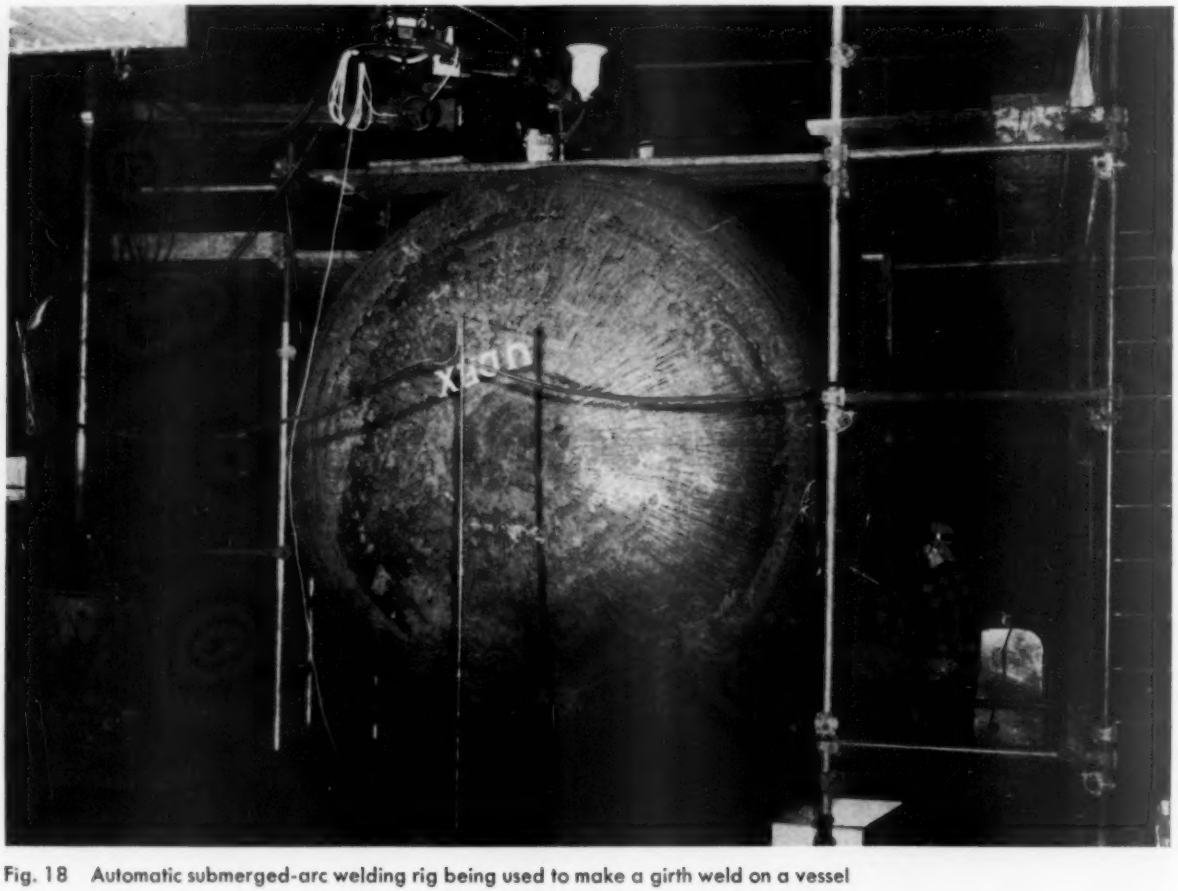


Fig. 18 Automatic submerged-arc welding rig being used to make a girth weld on a vessel

quite high, on a gradual slope upward from the driving positioner, to permit the ells to clear the floor during automatic welding.

Inert-Gas Metal-Arc Welding of Brass Pipe

Inert-gas metal-arc welding has found application in fabricating brass pipe. Previously, this piping was welded by the oxyacetylene process. This imposed a difficult preheat problem and the welder was uncomfortable, due to the heat. Figure 15 shows a flange being joined to a straight section of pipe, using a semi-automatic welding rig. A two-man fabricating crew is being used on this work. Argon is used as a shielding gas. Cooling water is circulated through the gun, from a reservoir located below the control box that can be seen in the background. The entire unit can be moved from weld to weld on long assemblies. The pan resting on the elevating table below the weld joint is partially filled with water so that any spatter which

falls into this pan stops fuming immediately. In more complicated assemblies as many welds as possible are done by roll welding. The remaining welds are made by welding the top half and then turning the assembly over to do the other half. Work is currently in progress to develop procedures for welding chrome and carbon-steel piping by inert-gas metal-arc welding.

Repair Applications

The application of submerged-arc welding for building up worn plug cocks has been quite successful. Figure 16 shows one that has been surfaced with Type 410 stainless steel. Prior to welding, carbon steel plates were fitted into the port openings to permit continuous welding. After finish-machining operations, these plates were cut out. This build-up operation has also been used on several other chrome alloys, as well as on carbon steel.

Figure 17 shows inert-gas metal-arc semiautomatic equipment being used to build up a worn valve seat in the brass liquid end of a reciprocating pump. We believe that this process has great possibilities in work of this nature.

Boiler Shop Applications

Boiler shop work involves the welding of parts made from plate or structural steel. Our biggest application is the welding of small tanks and pressure vessels. Automatic welding equipment must be suitable for making girth and longitudinal welds. Our first automatic welding rig, which was shown welding on pipe in Figs. 2 and 3, is shown in Fig. 18 making a girth weld on a vessel. A spool piece has been installed between the base and the column of the welding rig to elevate the welding head to the proper position. The scaffold on both sides of the vessel is required for the welders to operate the equipment. Longitudinal welds on this vessel were made by mounting the welding head on an adjustable-speed carriage which runs on a track. Figure 19 shows a similar weld being made on a section of rolled pipe. The trough beneath the welding joint is filled with flux, which is forced against the underside of the weld to serve as a backing.

To greatly simplify boiler shop work, the rig shown in Fig. 20 was purchased and installed. This boom and column type rig operates on 60 ft of track. The boom can be raised sufficiently to make girth welds on vessels up to 13 ft in diameter as the vessel is rotated beneath the head. Longitudinal welds can be made either by driving the entire rig along the track or by moving the boom in or out. The machine is equipped with a submerged-arc welding head powered by two 750-amp, continuous duty cycle motor-generator sets. They can be paralleled to give 1500 amps or can be operated individually.

The catwalk attached to the boom eliminates the need for scaffold. The catwalk can be easily removed from this rig to do jobs that the operator can do more conveniently while standing on the floor. Figure 21 shows the machine with the catwalk removed, ready to make an inside weld on a heat exchanger bonnet.

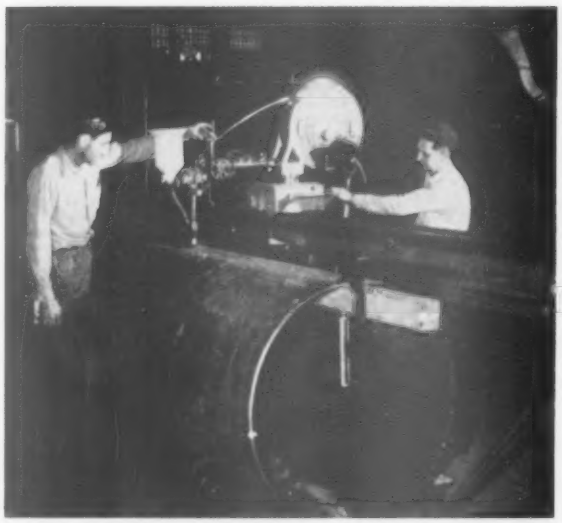


Fig. 19 Longitudinal weld being made on a section of pipe

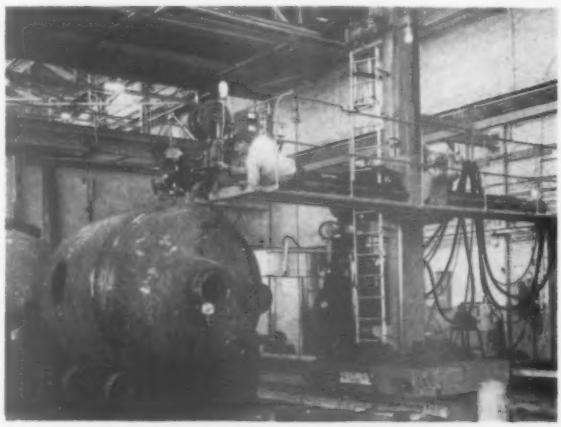


Fig. 20 Submerged-arc welder with operator on catwalk making a girth weld on a vessel.

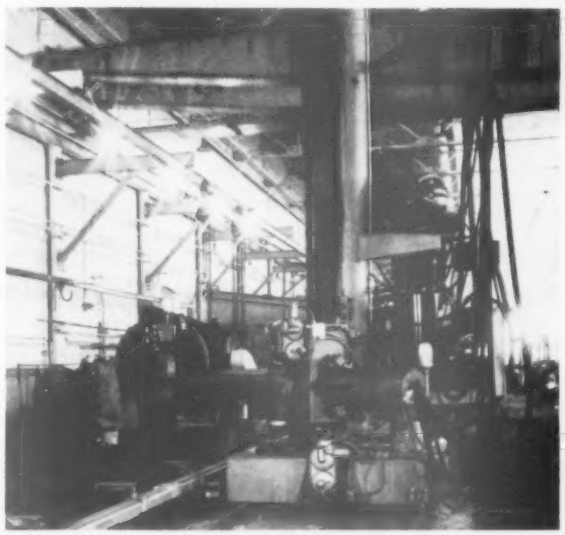


Fig. 21 Submerged-arc welder with catwalk removed making inside weld on a heat-exchanger bonnet

Typical application of spot welder equipped with Dekatron-type controls

A NEW CONCEPT FOR CONTROL OF RESISTANCE-WELDING MACHINES

Authors indicate that direct counting of cycles of line frequency, rather than the previous indirect method of timing, provides a control medium of absolute accuracy permitting unlimited function duration

BY W. J. FARRELL AND J. L. SOLOMON

ABSTRACT. This paper presents a new concept for control of resistance-welding machine functions. The status of prior concepts and their functional forms are reviewed, and their adequacy examined with regard to that required in an optimum control. It is found that the new concept of direct counting of cycles of line frequency, and impulses of secondary current, rather than the previous indirect method of timing, provides a control medium of absolute accuracy permitting unlimited function duration.

It is shown that this new concept satisfies the demands of industry for increased control reliability resulting from the in-

W. J. Farrell and **J. L. Solomon** are associated with Sciaky Bros., Inc., Chicago, Ill.

Presented at 1956 AWS National Spring Meeting in Buffalo, N. Y., May 7–11.

creased usage of resistance welding in critical primary structure dependability from an operational viewpoint, basic simplicity of circuitry, ease of serviceability and elimination of periodic maintenance calibration to assure functional accuracy.

Introduction

In the history of our technological development it is usually true that the original concept—on which a process, instrument or machine, is founded—is simply an extension of the specific technology existing at that time. Such developments viewed in retrospect may bear no resemblance to the logical approach dictated by the advancements of a later generation's technology. This does not mean that the original concept was illogical or unjustified; but rather, to the contrary, that it was reasonable and required because man can only base his reasoning on known facts and processes. . .he is limited by the technological level of his time.

Thus, succeeding generations continue to improve and refine the process, instrument or machine, without re-examining the validity of the original concept in the light of later facts and technological advances. This, of course, frequently results in methods and devices which are unnecessarily complex and restricted by artificial limitations.

Consider, for example, a visitor from Mars confronted with cross-sectional drawings—both of a modern high-power reciprocating aircraft engine, and of a turbo-jet engine. Assuming that his technology has developed along other lines than ours, our Martian would surmise that the piston engine—because of its complexity and highly refined detail design—was a recent development, while the patently simpler turbo-jet engine was an earlier form of propulsion. And, as a matter of fact, he would be fundamentally correct, for the basic turbine idea was employed as early as 200 A.D. by the Greek scientist, Hero of Alexandria. However, the application of the turbine principle to aircraft propulsion historically followed the application of the reciprocating engine.

The first internal combustion engines were, basically, modifications of the reciprocating steam engines in use at that time. This development was, therefore, compatible with the existing technology. Succeeding generations continued development and refinement of the reciprocating principle until the practical limit of this engine was approached. Finally, the reciprocating engine principle was re-evaluated when an adequate technology was attained which permitted effective interpretation of the turbo-jet propulsion principle.

Thus, re-examination of basic approach, and application of new ideas, are fundamental to significant technological advancement. This paper will discuss these factors in describing a new concept for control of resistance-welding machines.

Necessity for Improvement of Controls

It is axiomatic that for any change in method or concept to be justified it must first be shown that a need for change exists.

Resistance welding in its early days was generally applied as a substitute joining method. Little or no consideration was given to the possibilities of resistance welding in products especially designed for the process. This situation existed with few exceptions into the early 1940's, when the cost and weight-saving advantage of resistance welding forcibly brought this process to the attention of the aircraft industry. The impetus resistance welding received from this attention cannot be overestimated, for the highly successful experience of these people was observed by all branches of industry. It was found profitable and expedient not just to replace previous joining methods, but moreover to particularly design for resistance welding fabrication. Resistance welding has, therefore, been introduced into increasingly critical structures. In the aircraft industry today completely resistance-welded primary structures are not just drawing board speculations, but flying examples of the adequacy and possibilities of this joining method. Not only the airframe, but the jet engines themselves are functional proof of resistance-welded design.

These achievements, however, were only possible because forward looking resistance-welding machine manufacturers recognized and responded to the problems and the increasingly stringent requirements of the aircraft industry. Such considerations as drastic reductions in weld edge distance to reduce component weight, more rigid and encompassing quality-control standards and an ever-increasing variety of materials to be welded are but a few of the factors which have necessitated, and continue to require, increased accuracy and dependability in welding machine controls.

Two further industry requirements have added to the rising demand for improved controls. First is the problem of transferability of machine settings. The view is often taken that one machine is representative of its type, and this as a general statement is true. Yet, from a practical standpoint, exact transferability of settings from machine to machine is accomplished only with great difficulty—the results will probably be nearly the same, but not close enough for quality control purposes. This situation is neither reasonable nor desirable.

The last of the requirements to be mentioned is increased machine versatility. It has long been known, for instance, that the resulting weld is a product of four principal factors: the independent variables of current, force and time, and the dependent variable of weld resistance. Better understanding of the resistance welding process has added additional variables. For example, in the 1940's for aluminum, and more recently for steel, it was found that improved welding quality could be obtained by an increased force, called forging, following the actual weld force. Thus an additional variable is introduced which must be coordinated with the other four: the time relation of current and forge force. Increased machine versatility requires the addition of many such variables, the inclusion of which can, and has, led to unnecessarily complex control systems possessing artificial accuracy limitations.

Present Controls. . .The Concept of Timing

How has this situation developed? The art of

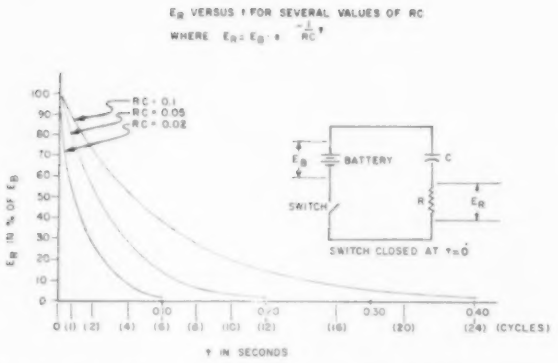


Fig. 1 The voltage across a resistor, in a series resistor-condenser circuit, as a function of the RC product in ohm-farads and the time (t) in seconds

resistance welding was born as the unintentional result of an experiment conducted by Elihu Thompson who, in 1877, discharged a Leyden jar (condenser) into the primary circuit of a voltage step-down transformer—thus fusing together the secondary circuit terminals which had been held together. Controls on early practical applications of this phenomena were simple. Duration of welding current and pressure application was determined solely by the machine operator's intuition and experience, connection of the transformer primary to the power supply being accomplished by the operator's manual actuation of a contactor. Cam and pneumatic delay devices were soon developed to satisfy the need for more reliable timing controls. Thus it can be seen that the concept of timing for control of resistance welding functions was a natural one for the technology of that time.

The application in the early 1920's of electronic devices to the problem of function timing was a tremendous step ahead in the search for a more accurate control. These devices employed the principle that the time of charge or discharge of a condenser in a resistor-condenser electrical circuit can be regulated by the magnitude of the product of the component values—the RC time constant—and the voltage supplied to the

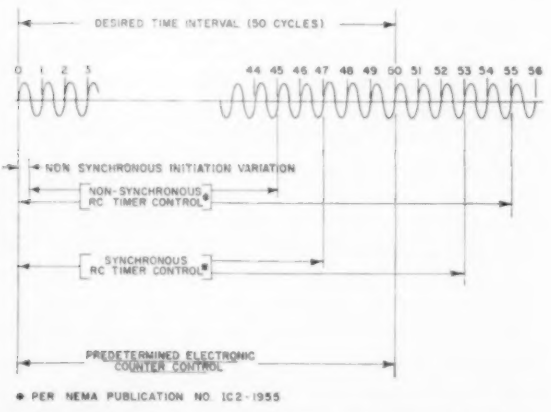

DESIRED TIME INTERVAL (50 CYCLES)
0 1 2 3
44 45 46 47 48 49 50 51 52 53 54 55 56
NON SYNCHRONOUS INITIATION VARIATION
NON-SYNCHRONOUS RC TIMER CONTROL*
SYNCHRONOUS RC TIMER CONTROL*
PREDETERMINED ELECTRONIC COUNTER CONTROL
* PER NEMA PUBLICATION NO. IC2-1955

Fig. 2 Accuracy of nonsynchronous, synchronous and predetermined electronic counter controls

circuit. This relation is shown in Fig. 1. Thus the natural development has been a timing circuit for each function.

Resistance-capacitance timing circuits, utilizing either vacuum or gas tubes, fall into two general classes—nonsynchronous and synchronous. Properly speaking, the one difference between the two types is that the latter, due to certain additional circuits, is capable of initiating timing from exactly the same point on the voltage waveform. Accuracy for RC timers is customarily based on the timer range but may be approximately given as plus or minus 5% for synchronous timers, and plus or minus 10% for nonsynchronous timers.

Timers of this type are affected by several important factors which further decrease their reliability. These factors are the effects of aging, temperature and humidity on the resistor and condenser components. As can be seen in Fig. 1, any variation in the RC time constant for these or any other reasons is reflected in a corresponding variation in function duration. It is difficult to assign any exact magnitude to the influence of these factors—in some instances the error may be cumulative; and, in others, cancelling. However, it is a well-known fact that periodic recalibration of timing devices of this type is a necessity if a reasonable degree of function accuracy is to be obtained.

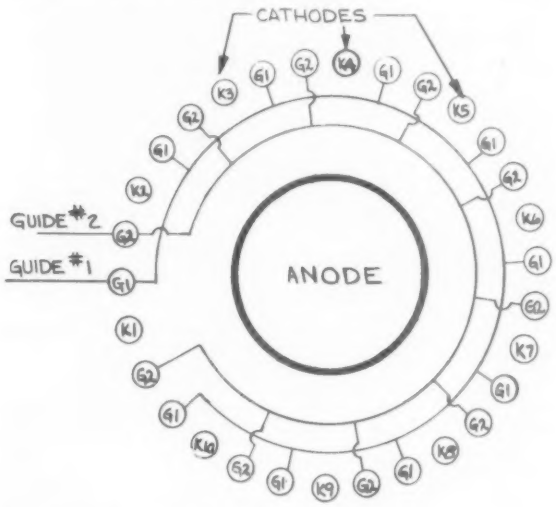
The Nature of the Problem...What Is to Be Controlled?

Having examined the necessity for improvement of controls, and the general features of present controls, consideration will next be given to the basic problem: What is it that is to be controlled?

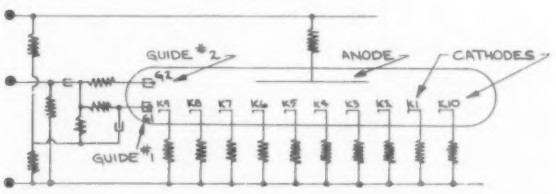
It can be seen that the basic problem is to control a multiplicity of functions without deviation either in function duration or in point of initiation. As was pointed out earlier, resistance welder functions have increased many-fold from the single item of weld duration. A typical welder program for certain heat-treatable, heat-resistant metals will consist of: *squeeze time*, during which the welding pressure level is established; *preheat time*, for stabilization of thermal gradients and preparation of the faying surfaces; *weld time*, during which the weld joint is created; *quench time*, to permit cooling of the weld; *postheat time*, during which the nugget is reheated to relieve quenching stresses and to reduce hardness; and *hold time* for retention of pressure on the joint until relatively cool. For automatic production an *off time* function may be added. Coordinated to this sequence is a paralleling pressure program consisting of a high pressure *precompression*, a lower pressure level for *weld*, and a high pressure *forge*. The pressure sequence is coordinated with the function sequence through two more timers: *low pressure delay*, which determines when the lower weld pressure will be initiated relative to the beginning of the preheat time; and *forge delay*, which determines the initiation of the high forge pressure relative to the weld, quench or postheat time. In addition, for pulsa-

tion welding, further timing circuits are required for determining *heat* and *cool time* durations. Thus far 14 timing functions have been mentioned. If the machine is required to weld light alloys, such as aluminum, or to operate as a roll-spot welder, additional timing functions would be necessary.

It should be readily apparent that the coordination of fourteen functions, each of which is important to the properties of the resulting weld, cannot be a simple accomplishment. Nor is the problem made any simpler by the inherent inaccuracy of resistor-condenser timing. This is particularly evident when the function durations are relatively long, and is illustrated in Fig. 2. For example, if only three functions—each having a nominal duration of 50 cycles—are used sequentially employing nonsynchronous timers, the cumulative time may be anywhere between 135 and 165 cycles. The case is somewhat better for synchronous timers, the cumulative time for the same



(A) Schematic illustration of element arrangement.



(B) Schematic of typical circuitry of cold-cathode glow-transfer type tube.

Fig. 3 Dekatron tube

case being between 142 and 158 cycles. Such timing variations unquestionably have an undesirable effect on reliability when welding sensitive materials, and when welding critical applications to quality standards.

Requirements of an Optimum Control

Having given some of the problems which presently exist in timing controls, the requirements for an optimum control will be discussed. These points can be stated simply, for their justification has already been reviewed. An optimum control should be: (1) capable of exact control of any function for any required duration without deviation; (2) multipurpose in nature, one unit being capable of handling all functions which occur in succession; (3) simple in design and principle, retaining this simplicity without regard to the number of functions served; (4) designed for maximum serviceability; (5) insensitive to component and power variations. Finally (6) the control dial settings should correspond to the actual whole number of cycles, or the number of impulses of secondary current produced for each function.

Solution of the Problem

The solution to this problem can be found by re-examining the concept to which welder controls have previously been designed. This concept has been *timing*. Originally, the operator himself determined time; later, time was determined by mechanical devices; and more recently, time was determined by electrical and electronic devices. If this approach is carefully analyzed it will be seen that the basic concept is a paradox: what is being done but timing time! The alternating current which supplies the welding machine power—which turns the synchronous motor—which runs the electric clock—what is this but time itself! And accurate not to one cycle out of ten, or one cycle out of one hundred, but accurate to a few cycles out of a year!

The solution to the problem, then, is to directly use this alternating power. The weld is not impressed by there being 0.01667 second in a cycle, nor is there any reason for using secondary reference. The weld is created by the *number* of cycles during which welding current flows. And that is the answer to control accuracy—not timing, but counting.

How the Concept of Counting Is Implemented

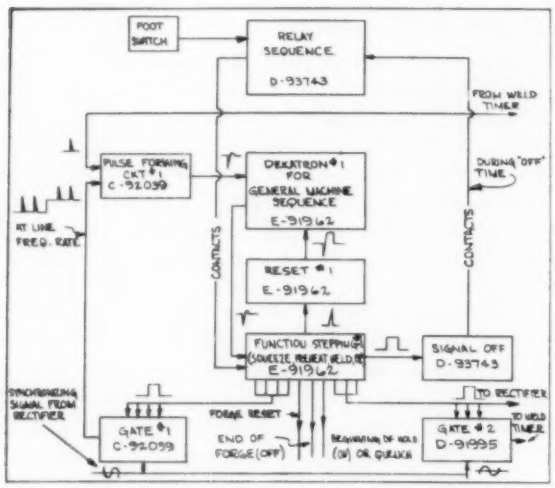
Thus the first requisite of progress is satisfied—the basic concept has been re-examined and the knowledge of a higher technological level applied—resulting in a direct and simple solution unencumbered by artificial limitations.

The implementation of this new concept of predetermined electronic counting for function control is made possible by the recently introduced cold-cathode glow-transfer tube known commercially as the Dekatron, which is schematically illustrated in Fig. 3(*A*).

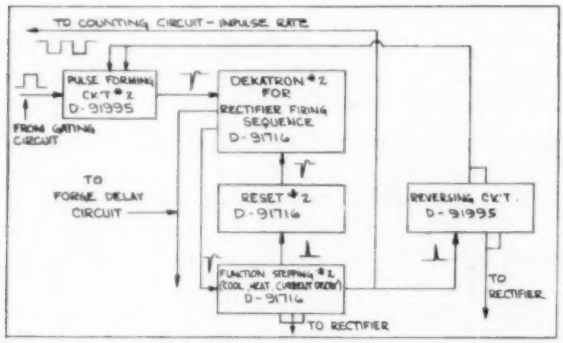
Briefly, this device consists of a common anode and a multiplicity of individual cathodes. Between the cathodes are two additional elements called guides, and designated Guide One and Guide Two. All the Guide One elements are internally connected together, and all the Guide Two elements are internally connected together—each group having a common connection available externally. The external cathode element terminals are connected through individual resistors to a common point. If a suitable potential is applied between the anode and the common cathode point, one of the cathodes will conduct. In the quiescent state, the guide elements are maintained at a positive potential above that of the cathode. If then a negative

pulse is introduced on the common Guide One terminal, the glow will transfer from the glowing cathode to the adjacent Guide One element. If an incremental moment later (as the pulse is being removed from the Guide One terminal) a second negative pulse is introduced on the common Guide Two terminal, the glow will transfer from the glowing Guide One element to the adjacent Guide Two element. Inasmuch as the normal potential level of the guides is positive with respect to the cathode, when the negative pulse on the Guide Two terminal is removed the glow will transfer to the adjacent cathode. These negative pulses are derived directly from the 60-cycle power supply to the welder. Figure 3(*B*) illustrates the immediate circuitry associated with the tube. The voltage developed across the cathode resistor is used to deliver a signal for purposes of machine control.

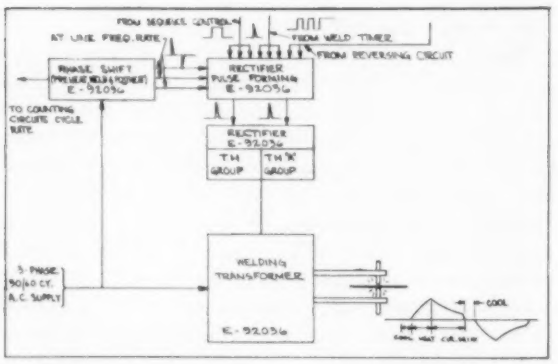
In specific control circuit combinations, pulse count-



(A) Block diagram of sequence control.


TO COUNTING CIRCUIT - IMPULSE RATE
PULSE FORMING CK'T #2 D-91995
DEKATRON #2 FOR RECTIFIER FIRING SEQUENCE D-91716
FROM GATING CIRCUIT
TO FORGE DELAY CIRCUIT
RESET #2 D-91716
REVERSING CK'T D-91995
FUNCTION STEPPING #2 (COOL, HEAT, CURRENT FLOW) D-91716
TO RECTIFIER
TO RECTIFIER

(B) Block diagram of weld timer.



(C) Block diagram of rectifier.

Fig. 4 Predetermined electronic counter control

Fig. 5 Predetermined electronic counter as incorporated in a spot-welding machine

Fig. 6 Predetermined electronic counter as incorporated in a seam and roll-spot-welding machine

ing circuits and commutating stepping circuits are utilized in order to obtain the desired sequence of operations; for example, the control illustrated by the block diagrams in Fig. 4(*A*, *B* and *C*) is one utilized for a three-phase spot welder having the following general sequence functions: squeeze, preheat, weld, quench, postheat, hold and off time. All of the welding periods are measured in terms of impulses of secondary current, and all other functions are measured in terms of cycles of line frequency. Therefore, there are three periods in the general sequence control during which impulses are counted (preheat, weld and postheat), and four periods which are measured in cycles (squeeze, quench, hold and off). The system in general consists of five major divisions:

(1) Seven function-stepping impulse and cycle counting circuit (see Fig. 4(*A*)).

(2) A cool, heat and current decay cycle counting circuit (see Fig. 4(*B*)).

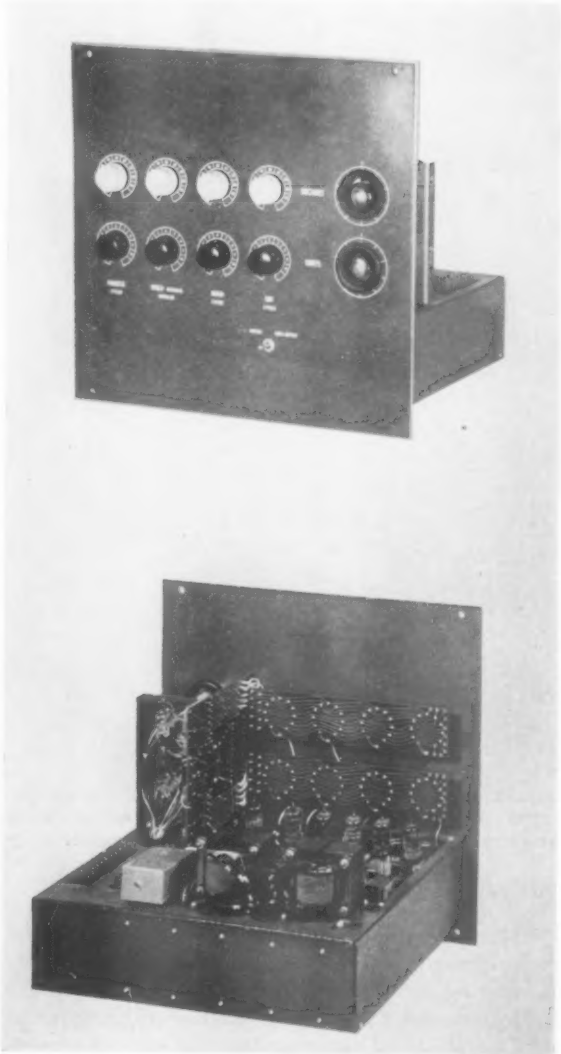


Fig. 7 Front and rear view of "Squeeze-Weld-Hold-Off" function chassis

(3) A forge delay cycle counting and valve operating circuit (see Fig. 4(*A*)).

(4) A rectifier pulse forming and firing circuit (see Fig. 4(*C*)).

(5) Relay sequence including time delay, safety, heat retraction and foot-switch circuits (see Fig. (4(*A*)).

Figure 5 is a photograph of such a spot welder. Shown in Fig. 6 is the predetermined electronic counter control, as applied to a seam welder.

It is not the purpose of this paper to develop the application of this device, but rather to discuss a new concept in resistance-welding-machine controls. Therefore, consideration will now be given to the merits of this new concept based on requirements of an optimum control, as previously defined.

The first requirement was: exact timing of any function of any duration without deviation. It is readily apparent that the use of the natural frequency of the power supply to directly control the function duration must result in perfect accuracy, for by definition the yardstick of accuracy is the frequency of the power supply. Nor is there any problem in obtaining extended time ranges: one Dekatron will count ten cycles, a second tube cascaded with the first will extend the maximum count to one-hundred cycles; a third tube similarly arranged will count to one-thousand cycles; and so *ad infinitum*.

The second requirement was that the realization of the concept be multipurpose in application. This condition is a necessity in the many functional machines of today and it has been eminently satisfied in this new control. As was observed in the block diagram only one Dekatron circuit is required to control the seven successive functions of squeeze, preheat, weld, quench, postheat, hold and off; a second Dekatron circuit for the similar paralleling functions of cool, heat and current decay; and a third Dekatron circuit for the paralleling function of forge delay. Observe how this reduces the complexity of the control: Whereas previously eleven RC timers, of limited accuracy and range, would have been required; now—utilizing this new concept of predetermined electronic counting—only three Dekatron circuits, of absolute accuracy and unlimited range, are necessary. In Fig. 7 is shown a close-up of a four-function chassis.

Simplicity of design and principle, featuring maximum serviceability, which are the third and fourth requirements, have similarly been accomplished and are seen in Fig. 8. The associated circuitry for the control has been reduced to a minimum and standardized in plug-in type units. All units are easily removable for servicing by disengaging one or more screws, as shown in Fig. 9. In accordance with modern practice these fasteners are of a type which remain integral with the unit. All units, interconnection plugs, etc., are pin-coded to assure proper placement. Compactness and maximum serviceability are particularly accented in the

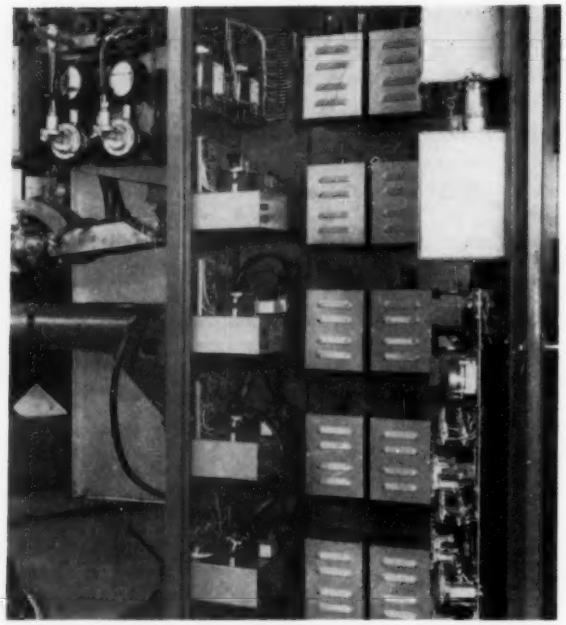


Fig. 8 Interior view of control cabinet showing function chassis and associated circuitry boxes

Fig. 9 Illustrating ease of function chassis addition or removal

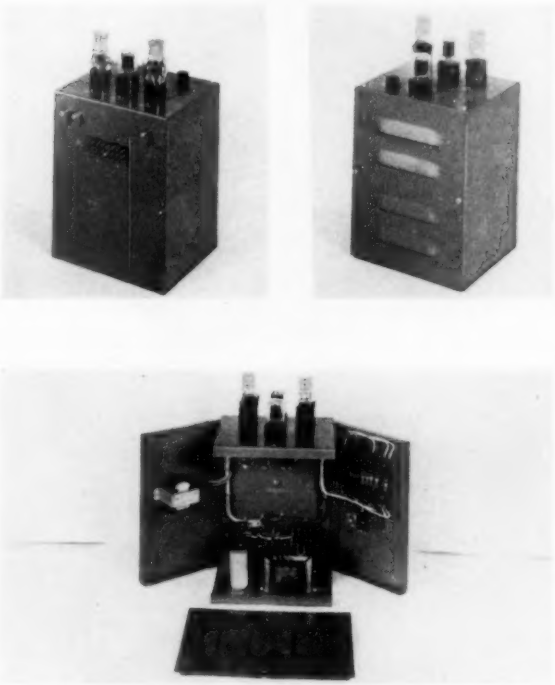


Fig. 10 Associated circuitry box has individual fusing, coded plug-in connector. Quick-disconnect self-retaining type screws and hinged side panels permit easy maintenance

folded box type construction of the power supply, gating circuit and peaking circuit plug-in boxes, shown in Fig. 10.

The fifth requirement was control stability. Because of the simplicity of the predetermined electronic counting concept and its functional implementation, no critical circuits are required. Over one year of prototype testing under all conditions was given to proving this point. The results of these tests have been overwhelmingly successful, proving beyond any doubt the soundness of the predetermined electronic counting concept.

The sixth requirement specified exact agreement between control dial setting and actual function interval produced. This has been accomplished because only absolute units are counted, because control knobs are of the positive adjustment type and are identified in these same absolute units and because the control is completely electronic—requiring no operating relay with its variable time constant from the beginning of squeeze to the end of hold. This permits standardization of machine settings, and permits transfer of settings from one machine to another with complete freedom.

Summary

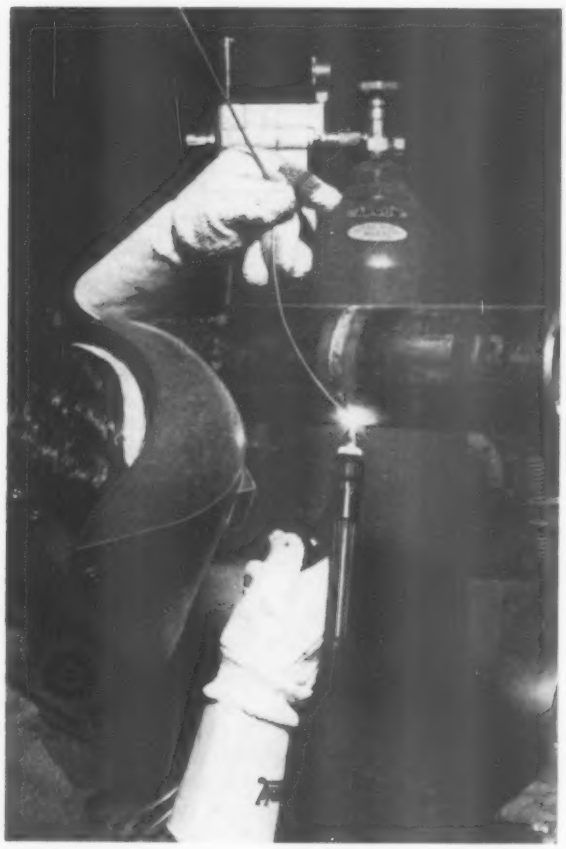
This paper has presented a new concept for control of resistance-welding machine functions. The status of prior concepts and their functional forms have been reviewed, and their adequacy examined with regard to that required in an optimum control. It was found that the new concept of direct counting of cycles of line frequency, rather than the previous indirect method of timing, provides a control medium of absolute accuracy permitting unlimited function duration.

This new concept satisfies the demand of industry for increased reliability resulting from an increased usage of resistance welding. More important, perhaps, to industry as a whole are the dependability of this control concept from an operational viewpoint, the basic simplicity of the circuitry, the ease of serviceability and, most important, the elimination of periodic maintenance calibration to assure functional accuracy.

THE APPLICATION OF INERT-GAS TUNGSTEN-ARC WELDING TO CARBON-STEEL PIPE

BY F. J. PILIA AND R. W. MINGA

Fig. 1 Welding of carbon-steel pipe in position by the inert-gas-shielded tungsten-arc process



New welding techniques and procedures are presented, together with a discussion of joint design, operator training and economics of application

Introduction

Thirty years ago, most piping systems fabricated in this country made use of threaded or flanged joints. Today, a large percentage of pipe is fabricated by welding. The cost of welding this pipe represents a large part of the cost to fabricate piping systems.

At present, carbon-steel pipe welding is accomplished in large part with the oxyacetylene and flux-coated metal-arc processes. In an effort to improve weld quality and to reduce costs, numerous fabricators have been investigating inert-gas tungsten-arc welding. Results are most encouraging and indicate that, with the tungsten-arc process, high-quality welds may be obtained at a low cost—lower than appears possible with other methods.

The tungsten-arc process has been used since World War II to weld stainless-steel piping systems. The quality of welds in stainless piping prompted fabricators to carry on investigations with carbon steel. It was found that the tungsten-arc process produced appreciably higher weld quality in carbon-steel pipe and eliminated the need for backing rings. During these investigations, tungsten arc welding was found to be more economical than metal-arc or oxyacetylene for completing welds.

The application of tungsten-arc welding to carbon-steel pipe requires new welding techniques and filler wires. It is, therefore, the purpose of this article to describe these techniques and to discuss joint designs, welding procedures along with techniques, operator training, and—finally—economics of the application.

Welding Requirements

Equipment

Conventional tungsten-arc welding equipment is used for carbon-steel pipe welding. Figure 1 shows an operator with a modern electrode holder making filler passes on carbon-steel pipe in the horizontal fixed position, using the weave-bead technique.

Field conditions may require use of a tungsten-arc

F. J. Pilia and **R. W. Minga** are Engineers, Development Laboratory, Linde Air Products Co., Newark, N. J.

Presented at the 1955 AWS National Fall Meeting in Philadelphia, Pa., October 17–21.

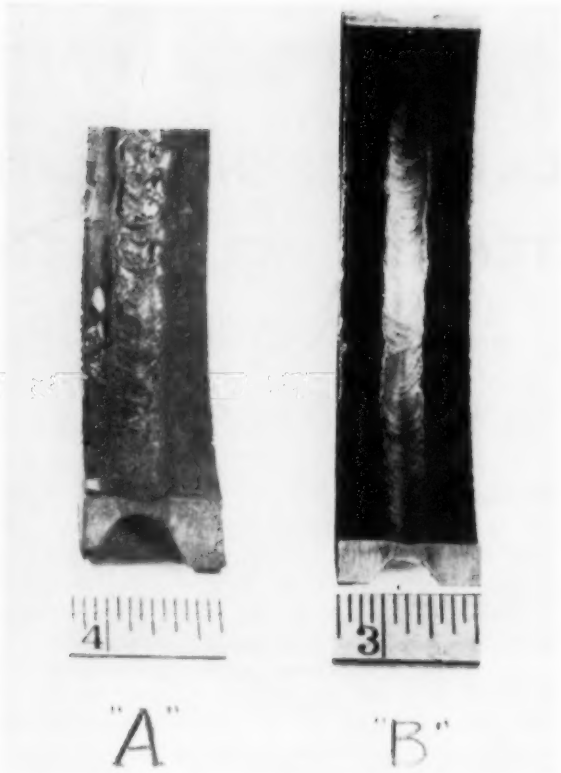


Fig. 2 Effect of argon backing (Section A—welded in air; Section B—welded with argon backing)

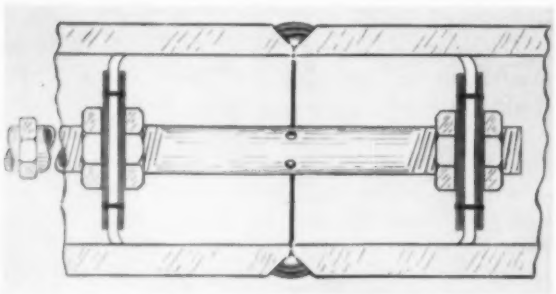


Fig. 3 Argon backing device (positioned with respect to weld)

electrode holder without water cooling. Under these conditions, the holder is derated in accordance with welding currents and operating factors imposed on the holder. Direct-current straight polarity obtained from conventional direct-current welding supplies (motor generators or rectifiers) is recommended for this application. A suitable supply of argon with pressure-reducing regulators and flowmeters is required to supply the shielding gas to the holder and to the underside of the weld if a gas backing is required.

Shielding Gases

Argon is recommended for shielding the tungsten electrode and weld puddle during tungsten-arc welding of carbon-steel pipe. Argon gives more uniform results than helium, because it is less sensitive to variations in arc length. Variations in arc length with helium produce considerable variation in penetration bead uniformity. In addition, argon flow rates are generally one-third to one-half of those required for helium, resulting in greater gas shielding economy.

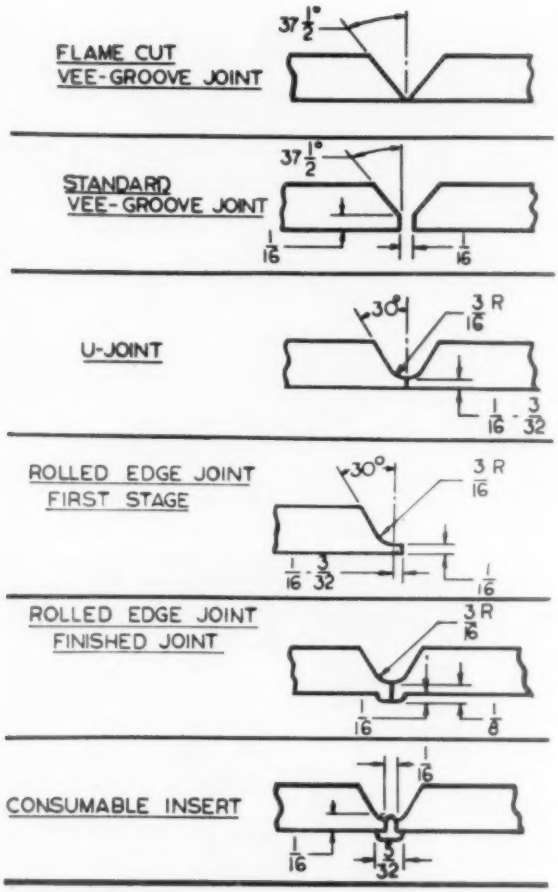


Fig. 4 Basic joint designs

Backing Gases

Argon, helium, nitrogen and carbon dioxide have been investigated as backing gases. It has been found that argon produces the most uniform penetration bead. The backing gas will pass through the unwelded joint and combine with the shielding gas from the tungsten-arc electrode holder. If different gases are used for the holder and backing, severe welding disturbances may occur. When nitrogen and carbon dioxide are used as a backing gas, the physical properties of the weld change due to the breakdown and subsequent chemical reaction of these gases with the underside of the weld. An increase in hardness and loss of ductility occurs, when nitrogen is used as a backing gas. Carbon dioxide breaks down to form oxygen and carbon monoxide. The oxygen reacts with the underside of the weld and increases the tendency toward porosity formation, especially in rimmed steels.

Figure 2 illustrates the effect of argon backing on the penetration bead inside the pipe. Section A is a weld

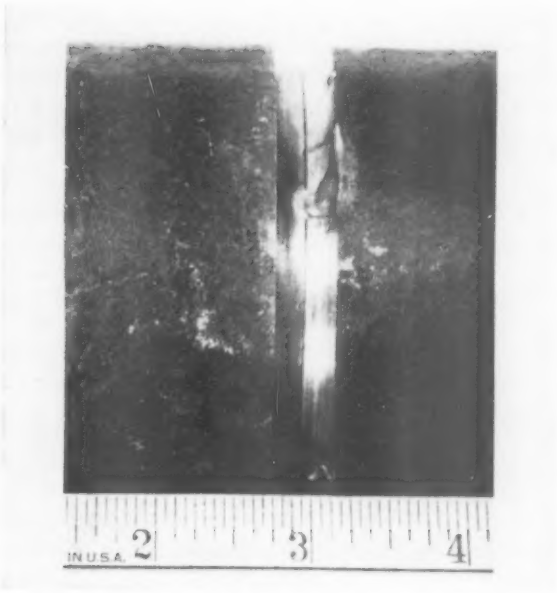


Fig. 5 Weld tacks carried to side of joint

made without argon backing, and Section B is made with argon backing. The irregularities and oxide present in Section A should be noted as compared to the smoothness and uniformity of Section B. Furthermore, Section A made without argon backing is more uniform than penetration beads made with the metal-arc or oxyacetylene processes.

Ways of Applying Gas Backing

Backing gases may be confined to the weld area by paper baffles, by completely filling the pipe with shielding gas or by using a removable backing device such as shown in Fig. 3. This device consists of two flexible rubber washers supported on each side with steel washers and spaced far enough apart to shield the underside of the weld. The two baffle assemblies may be connected with a piece of pipe or flexible tubing, depending upon the requirements of the joint. A substantial purging flow is used for a short period of time to replace air present between the two baffles. A general rule of thumb is six volumes of inert gas for each volume present between the baffles. After the air has been removed, a backing gas flow of 3 to 5 cfh is sufficient to continue protection on the inside of the pipe. If an oxide-free penetration bead is required, the device should be left in place until the weld is complete. This device is easily inserted and removed from the pipe.

On the vee or other joints where filler wire is used, for the root pass, the general tendency is not to use gas backing. With joint spacing, gas backing generally is not employed unless the extra weld quality is required. When gas backing is required with joint spacing, higher than normal gas backing flow rates must be used in order to maintain the effectiveness of gas backing in the presence of the opening.

Gas backing is recommended for highest quality penetration beads when welding tightly-fitted joints or joints with root openings.

Filler Wire

The tungsten-arc process presents no difficulties with respect to porosity when welding killed-steel pipe. For rimmed-steel pipe, however, a filler containing sufficient deoxidizers must be added to the weld puddle. Highly-deoxidized filler wires suitable for this purpose have recently been made available in straight 36-in. lengths ranging in size from $^1/_{16}$ to $^1/_8$-in. These filler wires produce equal results on rimmed and killed steels, permitting the use of a uniform welding procedure for both grades.

Joint Designs

A wide variety of joint designs may be used with the tungsten-arc process. They include the conventional 75-deg vee with a $^1/_{16}$-in. nose, the vee joint with a sharp nose (prepared by machining or flame-cutting), the U-groove, the U-groove with consumable inserts and the U-groove with a rolled edge. The nominal dimensions of these joint designs are shown in Fig. 4.

Preparation for Welding

The weld joint should be dry and free from oil, grease, paint, heavy rust or scale for a distance of $^1/_4$ in. on all sides (inside and outside the pipe) of the weld joint.

The pipe is fitted into position and if joint spacing is used, pieces of wire with the same diameter as the spacing is placed between the pipe ends. If gas backing is used, the inside of the pipe in the weld area is purged of air before tack welding. The power supply is adjusted to the proper current setting, and the joint is tack welded. The pieces of the wire used for spacing the joint are then removed.

Manual Welding Techniques

In order to describe the techniques required for tungsten-arc welding of carbon steel pipe, welding techniques are subdivided into four phases: (1) Tack welding, (2) root pass, (3) filler passes and (4) finish pass.

Tack Welding

When filler wire is to be used for the root pass, it is required also for making the tack welds. These welds, usually $^3/_8$ to $1^1/_2$ in. long, are spaced evenly along the joint and may be used as part of the root-pass weld. When filler rod is not used on the root pass, then the tack welds are approximately $^1/_8$ in. long and are made every 2 to $2^1/_2$ in. apart.

After tack welds are made, the weld puddle is maneuvered to the sides of the pipe joints as shown in Fig. 5. The welding speed is then increased until the weld puddle becomes small enough so that the arc may be interrupted without causing a crater defect.

Root Pass

Factors affecting root-pass techniques are joint design, the position of the pipe and the use or nonuse of filler wire.

Filler wire is usually required for the root pass on 75-deg vee joints with a $^1/_{16}$-in. nose. Joint spacing

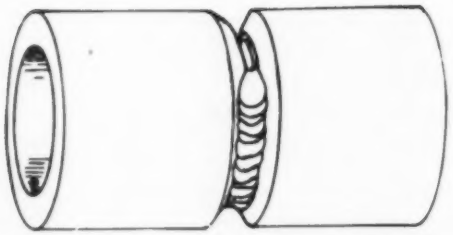


Fig. 6 Shape of weld puddle for complete penetration on root pass in 75-deg vee joint with $^1/_{16}$-in. nose with root opening

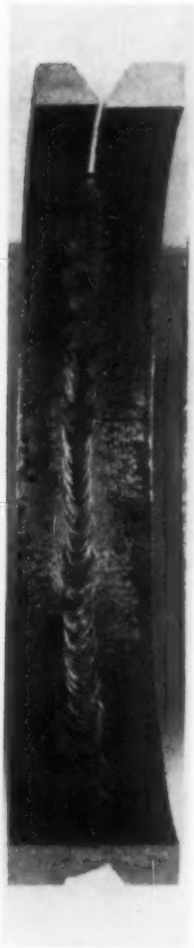


Fig. 7 Penetration bead on root pass for 75-deg vee joint with $^1/_{16}$-in. nose welded in horizontal fixed position

should be approximately equal to the nose thickness, if filler wire is used. Penetration is complete when the weld puddle is roughly wedged-shaped with rounded corners as shown in Fig. 6.

On joints prepared with a 75-deg vee and $^1/_{16}$-in. nose welded in the fixed horizontal position, strict adherence to the techniques of penetration control is required to prevent excessive sink in the overhead portion of the weld. Penetration bead sink may occur on the inside of the pipe, but normally is less than $^1/_{32}$ inch. Figure 7 shows the penetration bead usually obtained in the horizontal fixed position.

The welding of the 75-deg vee with a $^1/_{16}$-in. nose and a root opening in the vertical fixed position (joint horizontal) normally requires the addition of filler metal. The formation of the weld bead is displaced approximately $^1/_{16}$ in. above the centerline of the joint.

When using a standard 75-deg vee with a $^1/_{16}$-in. nose and no root opening, fusion of the root of the joint is usually made without filler metal. Penetration is complete, when a sharp point forms at the leading edge of the puddle at the bottom of the vee as indicated in Fig. 8. When the point becomes rounded, or a re-entrant notch is formed, penetration is incomplete and travel speed must be reduced to correct this condition.

In welding the overhead portion of the horizontal fixed position weld, the centerline of the electrode is held to one side of the pipe by approximately $^1/_{16}$ in. Otherwise, the techniques used are the same as for the rolled weld.

In the vertical fixed position, the operator compensates for the effect of gravity by directing the electrode $^1/_{16}$ in. above the horizontal centerline of the joint. If the electrode is pointed toward the centerline, excessive sink or concavity will occur in the penetration bead on the inside of the pipe.

When using 75-deg vee joints with a sharp nose (prepared by machine- or oxygen-cutting), joints are tacked without a root opening and filler wire introduced almost immediately after the arc is struck. A "keyhole" appearance (see Fig. 9) produced by the weld puddle and a small hole through the joint indicates complete penetration. The weld should then be advanced along the joint. When the hole of the "keyhole" lengthens and the front of the puddle widens out, the electrode should be pointed toward the filler wire to permit more rapid melting of the wire and to avoid burn-through.

The "keyhole" appearance is destroyed if the weld advances too rapidly or filler wire is added too quickly. To offset this, the electrode should be pointed more toward the centerline of the pipe and filler wire withheld until the puddle returns to the normal "keyhole" shape.

The 75-deg vee joint with a sharp nose may be welded in the horizontal fixed position with the technique described above. The welding sequence is the same as for the 75-deg vee joint with a $^1/_{16}$-in. nose.

The three U-groove joint designs—the standard, the consumable insert and the rolled edge—are capable of producing the highest quality root-pass welds obtainable with the tungsten-arc process. Generally, U-groove joint designs do not require as high an order of skill on the part of the operator as the vee joints. The consumable-insert and the rolled-edge designs

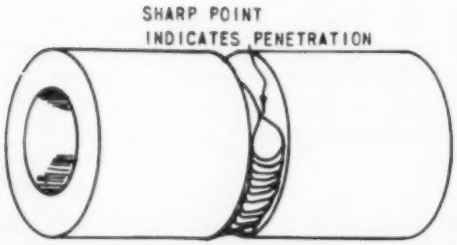


Fig. 8 Shape of weld puddle for complete penetration on root pass for 75-deg vee joint with $^1/_{16}$-in. nose without root opening

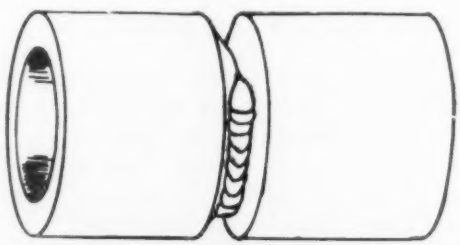


Fig. 9 Shape of puddle (small hole through joint) for root pass on 75-deg vee with a sharp nose

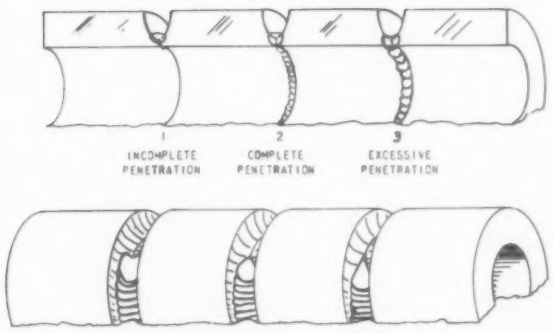


Fig. 10 Penetration control in U-groove joint

produce reinforcement on the inside of the pipe, even in the overhead position.

When welding the U-groove joint design, penetration is complete when the leading edge of the weld puddle becomes flat and tends to come to a point. An increase in travel speed and arc length will overcome excessive penetration. Various stages in penetration control are illustrated in Fig. 10.

The consumable-insert joint makes use of filler wire inserted as a ring or a washer especially shaped to be retained by the joint and offers the possibility of preplacing selected filler materials in the root of the joint. Close dimensional control usually is required.

The rolled-edge joint makes use of an upset produced by rolling the nose of a U-groove joint in order to preplace filler metal that will flow into the weld puddle to produce reinforcement on the inside of the pipe. This design is not critical with regard to dimensional control or misalignment of the joint. Therefore, it is somewhat easier to use than the consumable insert.

Penetration is complete in welding both types of joints when a rise occurs in the weld puddle. With the rolled-edge or consumable-insert joint, the uniformity of the puddle rise indicates the uniformity of penetration. Inert-gas backing is required to produce satisfactory results. Welding currents and welding speeds are somewhat lower than speeds usually obtained with vee-groove or standard U-groove joint designs. The same techniques described for the horizontal rolled position weld are used for the horizontal fixed position and vertical fixed position welds. Figure 11 illustrates the inner surface of both a partially complete and a completed weld in a rolled-edge joint welded in the horizontal fixed position. Figure 12 shows a section of weld made in the consumable-insert joint in the vertical fixed position.

Termination of the root pass weld bead for pipe in any position is carried out by maneuvering the weld puddle to the side of the joint and increasing the welding speed to reduce the size of the weld puddle. The arc is broken when the puddle becomes small enough to be interrupted without causing a crater defect.

Filler Passes

After the root pass weld is made, filler passes are

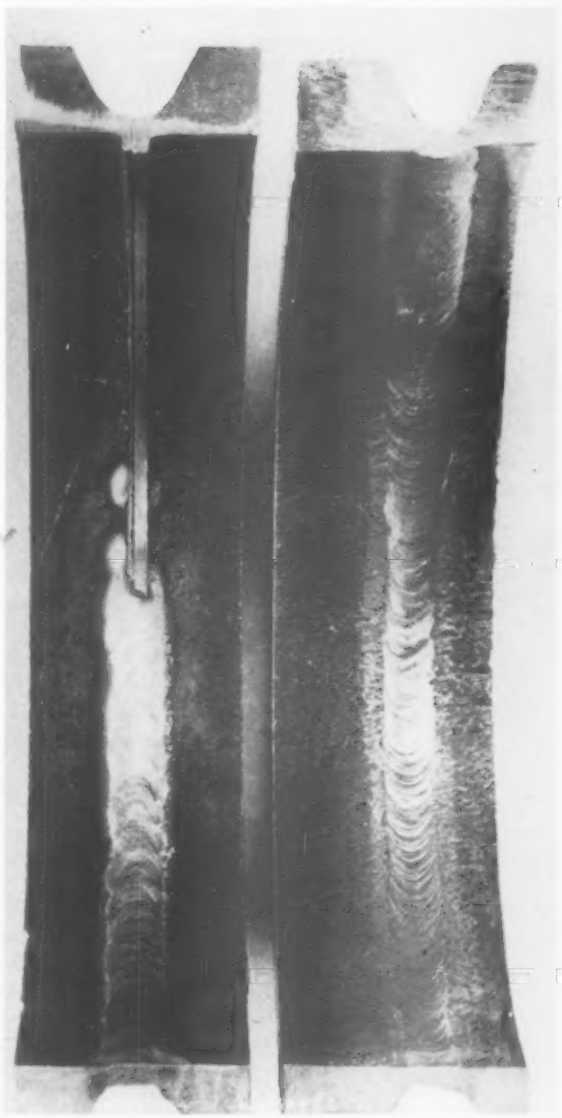


Fig. 11 Root-pass welds in U-groove joint with a rolled edge (welded in horizontal fixed position)

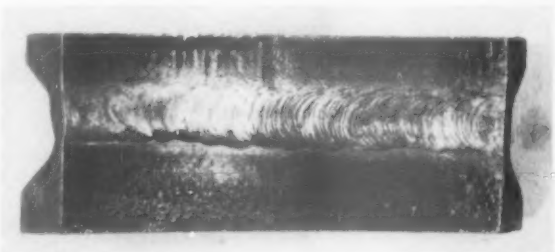


Fig. 12 Root-pass weld in U-groove joint with consumable insert (welded in vertical fixed position)

used to fill the joint to within approximately $^1/_{16}$ in. of the surface of the pipe. A larger weld puddle can be used on pipe in the rolled position than in horizontal fixed or vertical positions. In the latter instances, a

smaller weld puddle is used to overcome the effect of gravity. This means that a correspondingly smaller welding current is used. Stricter adherence to techniques of weld bead penetration and control is also required for the position welds. Filler passes can be made with either the stringer-bead or weave-bead technique on pipe in the rolled or horizontal fixed positions. The stringer-bead technique, however, is required on pipe in the vertical fixed position.

Penetration in making filler passes on pipe joints will be complete if the weld puddle remains fluid, flat in front, and blends into the sides of the joint or in the case of stringer heads, to the edges of other beads. Incomplete penetration and cold shuts will result if the weld puddle is allowed to pile up and become thick in front. If this condition occurs, filler wire should be withheld from the weld puddle until the puddle becomes fluid.

Excessive penetration, drop-through or distortion of the root-pass weld may occur if the weld puddle is allowed to become too large in making the first layer on top of the root-pass welds. When this condition occurs the weld puddle will appear very fluid and will be flat in front. The tungsten electrode should be slanted more toward the filler wire and the wire added as rapidly as possible to correct this condition.

At the overlap of the filler passes, weld beads should overlap by approximately one-third of their width. The filler passes should be uniform and the joint filled to approximately $^1/_{16}$ in. from the top of the pipe for the finish passes.

The weave bead may be used on pipe in only the *horizontal* position. The weld puddle should be fluid, flat in front of the filler wire and blended into the sides of the joint. If the puddle appears thick in front and poured into the pipe joint, penetration will be incomplete and cold shuts will occur. Filler wire then should be withheld from the puddle until it returns to its normal shape and appears to be fluid.

Filler passes made with the weave-bead technique should be approximately $^1/_8$ in. thick. The sequence for making weave beads is the same as for root-passes on pipe in the horizontal fixed position.

Fig. 13 Stringer-bead finish-pass weld on vertical pipe

The technique for making the *first* filler pass using the weave-bead technique in the U-groove joint is more critical than on the other joint designs, because the root-pass weld is only slightly thicker than the nominal $^1/_{16}$-in. joint edges. In this joint design, care should be taken to keep the filler wire in contact with the bottom of the pipe joint to absorb as much heat as possible from the root pass weld. The filler wire should be as large as the pipe size will permit (usually up to $^1/_8$ in. diam) and added to the front of the weld puddle. Penetration is observed by the way the weld bead blends into the sides of the joint. If the weld puddle remains fluid and blended into the sides of the weld joint, penetration will be complete in the center of the joint. The proper current setting may at first seem too low, but it is necessary to prevent drop-through.

Finish Passes

The weldment of finish passes must overlap the pipe joint $^1/_{16}$ in. on each side and must be $^1/_{16}$ in. higher than the pipe surface. Its contour should be uniform from the edges to the center of the weld. As with filler passes, finish passes can be made with either the stringer-bead or the weave-bead technique on pipe in the horizontal positions. However, the stringer-bead technique must be used on pipe in the vertical position.

In making stringer beads on pipe in the rolled or horizontal fixed position, undercutting is prevented by

Fig. 14 Weave-bead finish-pass weld

pointing the tungsten electrode approximately 20 deg toward the outside edge of the pipe joint for the stringer made on that side of the joint.

The technique of making stringer beads on vertical pipe is exactly the same as described for making filler passes with the stringer-bead technique on vertical pipe. However, overlap must be uniform along both joint edges. Figure 13 shows a finished weld made in the vertical fixed position.

In using the weave bead for finish passes, the tungsten electrode should be slanted toward the filler wire approximately 20 deg as compared to 30 to 40 deg for filler passes. The tungsten electrode should not be pointed toward either edge of the pipe joint. Filler wire is added only at the edges of the weld puddle. On weld beads over approximately 1-in. wide, filler wire may also be required in the center of the weld to maintain the desired weld-bead height. The addition of filler wire at the edges of the weld puddle prevents undercutting. Figure 14 shows a weld completed with the weave-bead technique.

Operator Training

There are significant differences between the tungsten-arc process and other methods for welding pipe. First, the tungsten-arc weld puddle is smaller than puddles obtained with other process; second, greater penetration is obtained with the tungsten-arc process; and third, this process is amenable to a higher degree of control on the part of operators. Because of these differences, welding operators will need to be given training in the tungsten-arc welding of carbon-steel pipe to obtain highest quality welds at the lowest possible cost. Even operators with tungsten-arc welding experience in other materials will require training in this process as applied to carbon-steel pipe.

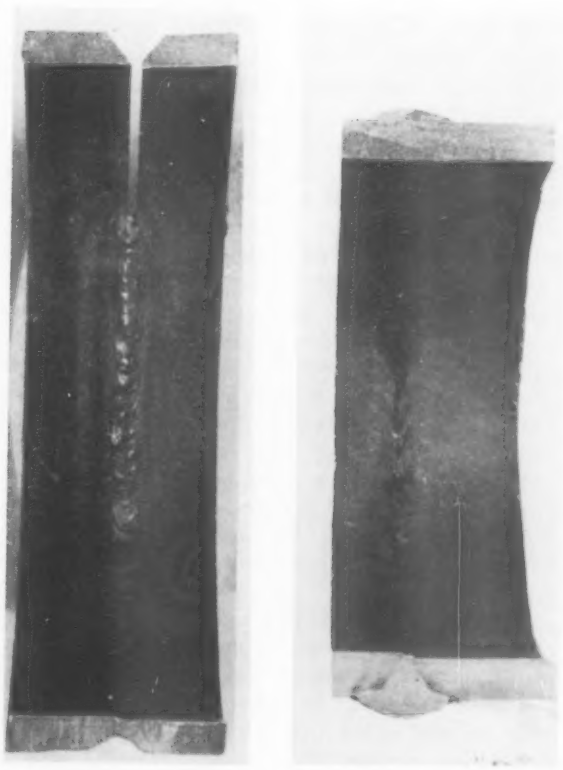
Operators should train with standard tungsten-arc welding equipment. Tungsten electrodes should be sharpened so the working end is one-third the diameter of the electrode and the taper extends $^{3}/_{8}$ to $^{1}/_{2}$ in. back from the end. Enough pipe should be supplied for four welded joints per hour of operator time; 3- or 4-in. Schedule 40 pipe is recommended. For the best economy, the pieces should be approximately 5 in. long and beveled on both ends. The pieces can be rebeveled and used until they are approximately 3 in. long. After this, the pieces are so short that the area of the weld will become too hot for proper control of the weld puddle.

Training should begin with simple instructions on how to use the tungsten-arc torch. From this, the operator should proceed to making tack welds and practice root-pass welds in vee joints on rolled pipe using filler wire. This stage of training will give the operator an opportunity to become familiar with changes in the shape of the weld puddle and with how to interpret these changes in controlling penetration and weld contour. The third stage of training should include practice in making filler and finish passes on rolled pipe. Finish passes should include both the stringer-bead and the weave-bead techniques.

In the fourth stage of training, the operator should practice completing welds on the top half of pipe in the horizontal position, then rolling the pipe 180 deg and completing the second half. This will give the operator practice in terminating and tying in the ends of weld beads. The welding operator should then proceed to root-pass welding and to the completing of welds in pipe in the vertical fixed position. Finally, the operator should practice making welds in pipe in the horizontal fixed position. Finish and filler passes in this position should be made with both the stringer-bead and weave-bead techniques.

When the operator has mastered the techniques of welding vee joints with filler wire on the root pass, he should practice making root-pass welds without filler wire on 75-deg vee joints with $^{1}/_{16}$-in. nose and on U-groove joints including rolled-edge and consumable insert joints. (A "killed" grade of steel should be employed when filler wire is not used on the root pass.) This practice should include completing welds in these joints.

An operator should not advance from one stage in training to the next until he has succeeded in making three consecutive welds with no defects in the one stage. It has been found that operators advance more rapidly



A B

Fig. 15 Comparison between tungsten-arc and metal-arc welds (Section A—tungsten-arc weld without gas backing; Section B—metal-arc weld without backing rings. Both welds made in the same position in standard 75-deg vee joint)

by training in teams of two. This gives one operator an opportunity to observe while the other is welding. This method of training tends to help an operator correct his own welding technique.

Welding Costs

The cost of tungsten-arc welding as applied to carbon-steel pipe has been subjected to laboratory and field analysis—the purpose of the analysis being to compare tungsten-arc and metal-arc welding on the same basis. Accordingly, gas backing was not used for tungsten-arc and backing rings were not used for metal arc. The quality of the tungsten-arc weld was superior in every case because of more uniform penetration and no evidence of slag inclusions. Sample results obtained with both tungsten-arc and metal-arc welding on the same basis are shown in Fig. 15 where Section A is the tungsten-arc weld and Section B is the metal-arc weld.

Procedures to analyze costs involved time studies into various phases of welding. Time required to complete welds was then converted into actual costs by applying a labor and overhead rate used by one fabricator on an actual job. Total cost was obtained by adding the cost of consumables to labor and overhead. In this case, consumables were filler rod and argon.

Costs for the tungsten-arc welding were compared to similar costs obtained with the covered-electrode and oxyacetylene processes. The results of this cost comparison are shown in Fig. 16 where the horizontal axis represents the pipe size and the vertical axis represents comparative cost. The joint design used for all processes was a standard 75-deg vee. As can be seen, the cost of welds completed with tungsten-arc welding is lower than welds completed with metal-arc or oxyacetylene welding. Although these costs were made on Schedule 40 pipe, available data indicate that this relationship will apply to other wall thicknesses. The curves shown are based on covered-electrode welds made without backing rings and tungsten-arc welds made without argon backing.

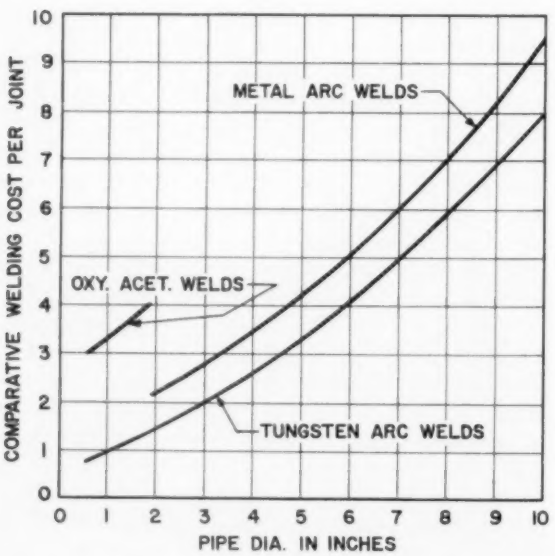


Fig. 16 Cost comparison between tungsten-arc, metal-arc and oxyacetylene welding on Schedule 40 pipe

Since deposition rates and welding speeds are essentially the same, savings with tungsten-arc welding result from the elimination of weld cleaning associated with metal-arc welding. Tungsten-arc welding speeds are, moreover, considerably higher than speeds obtained with oxyacetylene welding which is commonly used on the smaller sizes of carbon-steel pipe. Another saving—an intangible one—is in the fact that weld inspection and repair costs are less with the tungsten-arc process.

Conclusion

In one month alone—June 1955—carbon-steel pipe production in this country was equivalent to 14,500 miles of 3-in. Schedule 40 pipe. When one realizes that welding costs are a large part of the total cost to fabricate piping systems, one can then visualize the magnitude of welding costs confronting the pipe-fabrication industry throughout the United States.

The cost of welding is obviously of prime importance to pipe fabricators. In this respect, the tungsten-arc process when applied to the welding of standard joint designs in carbon-steel pipe results in savings not possible with other welding methods. Other advantages are:

1. Its use results in consistently higher quality welds.
2. It can be applied to both small and large size piping with the same techniques.
3. Less operator skill is required to obtain welds comparable in quality to welds obtained with other processes.
4. It can be applied to all grades of carbon steel, including both rimmed and killed grades.

The need for improving present methods of welding has caused many pipe fabricators to investigate tungsten-arc welding of carbon-steel pipe. The process has already found extensive use where backing rings were previously used, and for producing consistently higher quality welds at a lower cost than has been obtained with other processes.

Tungsten-arc welds meeting the most severe requirements have been made without grinding or machining the inside of the pipe. The inside of root-pass welds are cleaner than the inside of the pipe, itself, when an argon backing is used.

New techniques employing high deposition rates and new filler wire now make it possible to obtain completed joints of the highest quality. These filler wires also apply to rimmed steel pipe that has been troublesome to weld in the past. In addition, it has been shown that less operator skill is necessary to obtain high quality welds than is required for other manual welding processes. The inert-gas tungsten-arc process can be applied to all types and grades of weldable carbon and low-alloy steel pipe for better quality at a lower welding cost.

DESIGN AND TECHNIQUE REQUIREMENTS FOR ARC WELDING TITANIUM IN AIRCRAFT APPLICATIONS

Titanium welds which meet aircraft standards can be produced if correct joint design, choice of alloy, tooling, and welding techniques are employed

BY R. MEREDITH AND B. L. BAIRD

Introduction

In the arc welding of titanium for aircraft components, the welding engineer is faced with tooling and procedure requirements common only to a particular phase of the welding industry. Complex shapes must be fabricated from thin gage materials. The low design factors required by weight limitations make it necessary that the highest quality weld joints be produced.

This paper contains a discussion of jigging methods, welding techniques and design considerations required for making titanium welds which meet aircraft standards.

Contamination by Gas Absorption at Elevated Temperatures

Titanium has an unusually high affinity for oxygen, nitrogen, and hydrogen at elevated temperatures. Without the protection of an inert-gas shield during welding, the metal will absorb these gases from the atmosphere. This will result in brittle welds. To prevent this condition (except in rare instances), both the top and bottom sides of the joint must be protected during welding. This can be accomplished through (1) use of the inert-gas-shielded consumable or nonconsumable-electrode welding processes in conjunction with properly designed tooling, or (2) use of controlled atmosphere chambers. Equipment costs for welding large airframe assemblies by the latter method become almost prohibitive. Therefore in the work which led to the material discussed in this paper, every effort was made to develop joint designs, tooling, and welding techniques which would permit the making of high quality welds by the common inert-gas-shielded arc methods.

R. Meredith and **B. L. Baird** are associated with North American Aviation, Downey, Calif.

Presented at 1956 AWS National Fall Meeting in Cleveland, Ohio, October 8–12.

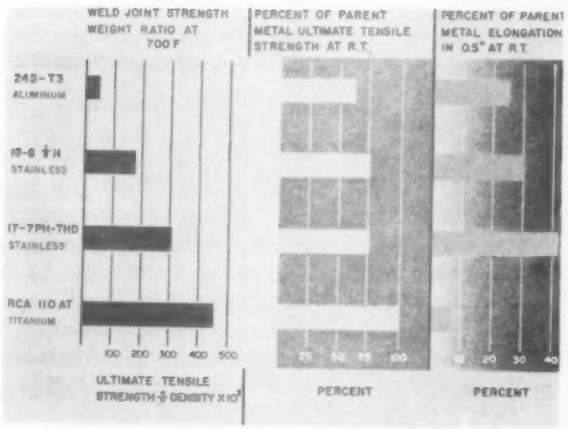

WELD JOINT STRENGTH WEIGHT RATIO AT 700 F
PERCENT OF PARENT METAL ULTIMATE TENSILE STRENGTH AT R.T.
PERCENT OF PARENT METAL ELONGATION IN 0.5" AT R.T.
2S-T3 ALUMINUM
18-8 ϯH STAINLESS
17-7PH-THD STAINLESS
RCA 110 AT TITANIUM
100 200 300 400 500
ULTIMATE TENSILE STRENGTH÷ DENSITY X10³
25 50 75 100
10 20 30 40
PERCENT
PERCENT

Fig. 1 Welded properties of various metals

In welding titanium, whenever possible, copper chill bars should be clamped tightly to the material immediately adjacent to the weld. In addition to insuring joint alignment, these chill bars quickly extract heat from the weld and base metal. This shortens the time the metal is at elevated temperatures, minimizes contamination by atmospheric gases, and reduces the base metal heat-affected area. The quenching effect also influences the final structure of welds of some alloys of titanium.

Weldability

Weld tests have demonstrated that commercially pure titanium and some alloys have good weldability. Table 1 contains data on the weldability of pure and alloy titanium using welding techniques already developed. An alloy which has good weldability is, for the purpose of this discussion, defined as follows: the alloy shall be one on which it is practical to make a production weld which will have mechanical and physical properties compatible with aircraft design requirements.

With the development of new welding techniques, alloys which are now of unknown and poor weldability may become alloys of fair or good weldability.

Comparison of Welded Properties of Various Metals

Figure 1 contains bar graphs illustrating comparative values of strength-weight ratio and per cent of base or parent metal tensile strength and elongation for welds made

Table 1—Weldability of Titanium

Weldability	*Stock*	*Material*	*Specifications*	*Remarks*
Good	Sheet and bar	RC55, MST GR III	AMS 4900	Weld setup should include hold down and backing bars for chill and alignment
		Ti 75		
		RC 70, RS 70	AMS 4901	
		MST GR III		
		Ti 100, MST Gr III	NA2-7128	
		RC-A110 AT	NA2-7127	
Fair	Sheet	RS110BX (3Mn-1Al)	None	Using the proper technique, joints high in tensile strength with fair ductility can be produced
		4 to 6Al-3 to 4V	None	
Poor	Sheet	RC-C110M		Development of new welding techniques may move these alloys into the fair weldability group
		RS 110A	AMS 4908	
		MST-8Mn		
Unknown	Bar	4 to 6Al-3 to 4V	None	Development of new welding techniques may move these alloys into the fair weldability group
		4Al-4 Mn	AMS 4935	
		RS-140	None	
		3Al-5Cr or Ti 155A	NA2-7129	

on 24S aluminum, 18–8 stainless steel, 17-7PH stainless steel and RC A110 AT titanium.

Strength-Weight Ratio

The comparison in Fig. 1 of the strength-weight ratios at 700° F of welded joints of titanium and of welded joints of the three other materials will show, from the standpoint of airframe design, the superior properties of welded titanium at elevated operating temperatures.

Tensile Strength

Figure 1 illustrates a characteristic peculiar to welded joints of some alloys of titanium. In the as-welded condition, welded joints of RC A110 AT titanium are equal in ultimate tensile strength to the base metal. Generally, this is not true of high strength materials. Ordinarily, some sacrifice in the ultimate tensile strength of the base metal must be expected when a welded joint is made.

Per Cent Elongation

Many common metals used in the aircraft industry suffer a loss in ductility when welded. However, the loss is even more pronounced in titanium than in other metals, as shown in Fig. 1.

Summary of Comparison of Welded Properties

A summary of the data presented in the graphs of Fig. 1, indicates that welded titanium is superior to other metals in strength-weight properties, and that welded joints of titanium have good tensile strength, but only fair ductility.

Preweld Preparation

Proper preweld preparation is the most important factor in controlling the incidence of gas porosity in titanium weldments. Quantitative tests run to determine the effect of various technique factors on porosity have shown conclusively that draw filing the joint surfaces prior to welding is the key to minimizing porosity. Among the technique factors evaluated in these tests were:

1. Travel speeds. Speeds of 2 through 15 ipm were investigated. X-ray analyses showed no correlation between travel speed and the incidence of porosity.

2. Quench rate. The quench rate was evaluated by comparing X-rays of welds made with and without copper chill. No correlation between quench rate and the incidence of porosity was established.

3. Preweld cleaning. Various cleaning techniques were used independently and in combination with each other. These included pickling in a nitric-hydrofluoric acid solution, degreasing in a trichlorethylene vapor bath, cleaning with an acetone rinse, rotary wire wheel brushing, draw filing, and machining to a RMS 62 finish. The combination of draw filing butting edges, plus rotary wire wheel brushing the adjacent surfaces, followed by cleaning with acetone immediately before welding, yielded welds with the minimum amount of porosity.

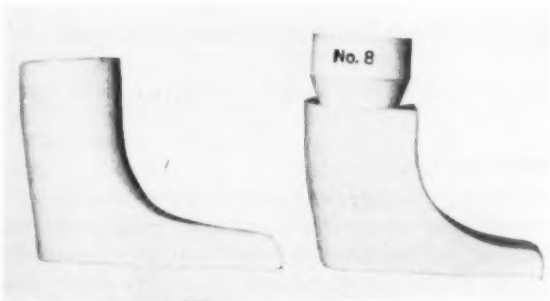


Fig. 2 Inert gas trailer nozzles

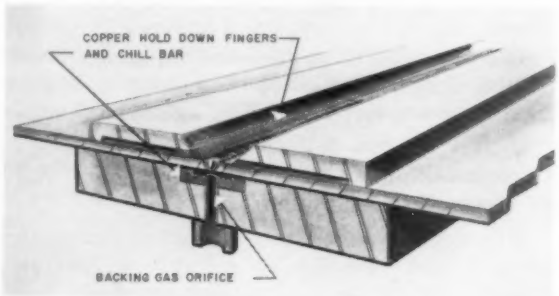


Fig. 3 Tooling for butt joints

4. Preweld vacuum annealing. X-rays of welds on material which had and had not been vacuum annealed before welding to reduce the hydrogen content were compared. Vacuum annealing did not reduce the incidence of porosity.

Welding Technique

In addition to preparing the joints properly before welding and using adequate tooling, welding titanium requires care and skill over and above that normally required for inert-arc welding other materials.

Because of its melting point and fluidity properties, alignment and fit up are particularly important.

Tack welds must be thoroughly buffed or filed to remove surface contamination before the final weld is made.

It is good practice to mechanically and solvent clean filler materials before welding. In the manual inert-gas tungsten-arc welding of titanium, material at the end of the filler rod, melted by a previous weld, must be cut off before commencing to weld. The heated end of the rod must never be removed from within the inert-shielding-gas cone while welding is in progress.

The importance of these factors was established by quantitative tests. Welds purposely contaminated by removing the end of the rod from the inert-gas shield were compared with welds made using every possible precaution. The purposely contaminated welds developed delayed transverse cracks and showed a nitrogen content of 0.943%. Welds made, taking care not to introduce contamination, developed no cracks and showed a nitrogen content of 0.334%. The nitrogen content was almost tripled by contamination introduced from the filler rod.

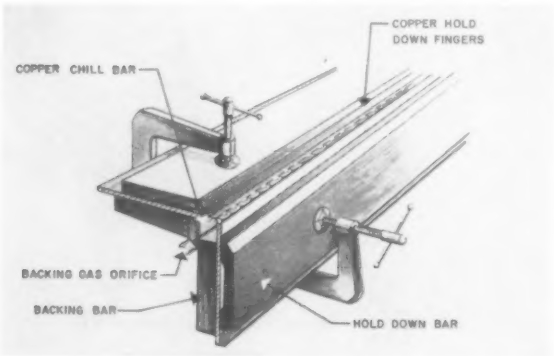


Fig. 4 Tooling for corner joints

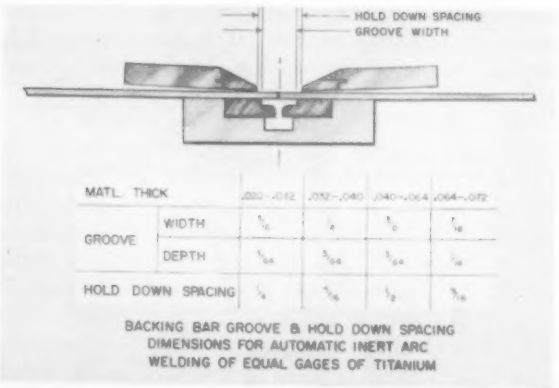


Fig. 5 Recommended hold-down bar spacing and backing bar groove dimensions

Tooling

Inert Gas Nozzles

Whenever possible, an inert-gas nozzle with a trailer attachment should be used to maintain gas over the weld until it cools to below 1000° F. Figure 2 is a photograph of two trailer nozzles typical of those used for welding titanium.

Hold-Down and Backing Bars

Whenever possible, hold-down and backing bars must be used to align and rigidly fix the joint during welding. The airframe designer must, therefore, provide space for the use of these fixtures. Figures 3 and 4 are sketches illustrating the use of steel hold-down and backing bars in making a corner and a butt weld. It is usually recommended that the fingers of the hold-down bars be made of copper, and that a copper insert in the backing bar be used to provide chill as shown. Figure 5 contains recommended hold-down bar spacing and backing bar groove dimensions.

Accessibility to Backing Gas

With very few exceptions, inert-gas shielding is required on both sides of welded joints. In most cases, a method of tooling must be devised to permit the gas to be expelled under very low pressure over the back of the weld. Therefore, both the airframe designer and the tool designer should bear in mind that nearly all welded joints must be accessible from both sides. This must be true even after final assembly or repair welds cannot be made.

Weld Fixtures

Weld fixtures are commonly used to provide joint alignment and chill during welding. Basically, fixtures most commonly used for welding titanium contain a horizontal mandrel with pneumatically operated hold-down fingers which press the work against a grooved backing bar. The weld joint is centered directly over the groove in the backing bar, and inert gas is passed through orifices in the bottom of the groove. The size and pattern of spacing of the orifices in the backing bar are arranged to insure gas diffusion along the entire length of the backing bar groove. Figure 6 shows a typical fixture used for welding titanium subassemblies. Fixtures of this type minimize the heat-affected area, shrinkage, and distortion.

Variations in Methods of Applying Backing Gas

There are numerous methods of applying backing gas to protect the side of the weld opposite the arc from contamination when jigs cannot be used. For example, a welder's helper, by watching the color of the back side of the weld, can direct inert-gas flow from a tube

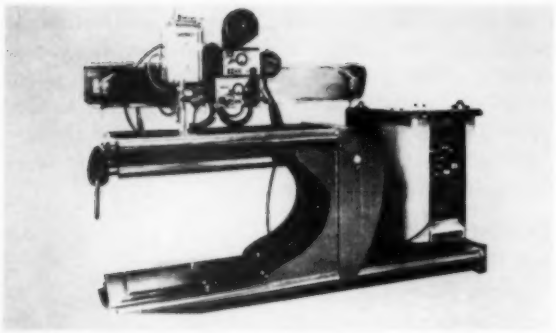


Fig. 6 Fixture used for welding titanium subassemblies

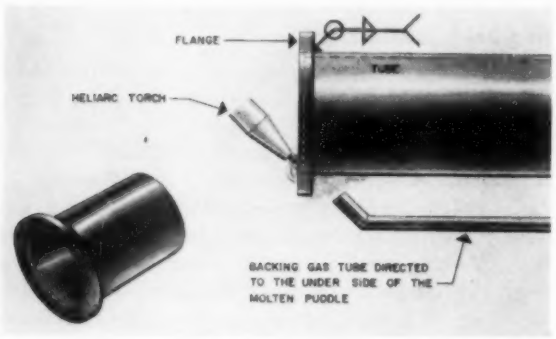


Fig. 7 Manual application of backing gas to the root side of a weld

to the root side of the weld puddle. This method is illustrated in Fig. 7. Other methods include enclosing the side of the joint opposite the arc in a compartment made of a material such as metal foil or cardboard and masking tape, or fastening a section of flexible tubing to the joint. These latter two methods are illustrated in Fig. 8. In these cases, inert gas is allowed to flow into the compartment surrounding the side of the joint opposite the arc. After a purge of a few minutes, the weld is made.

Welded Joint Design

Butt Joints

As a general rule, butt joints are preferred over other types of joints because they can carry greater loads and are easier to weld. They are also easier to inspect both visually and radiographically. However, they require precise trimming and fit-up, as well as jigging to maintain proper alignment. Figure 9 is an illustration of a butt weld on a tank fitting, showing schematically both the joint and the required tooling.

Corner Joints

Corner joints, second in preference only to butt joints, frequently require less elaborate tooling and less precise trimming and fit-up. Figures 10 and 11 are illustrations of joint fit-up for various types of welds on corner joints.

Figure 10 shows a weld joining three sheet sections (right hand illustration) and a self-jigging weld (left

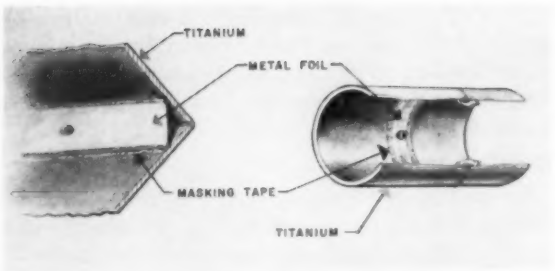


Fig. 8 Use of a compartment for maintaining backing gas at the weld root

Fig. 9 Square butt weld on a tank fitting

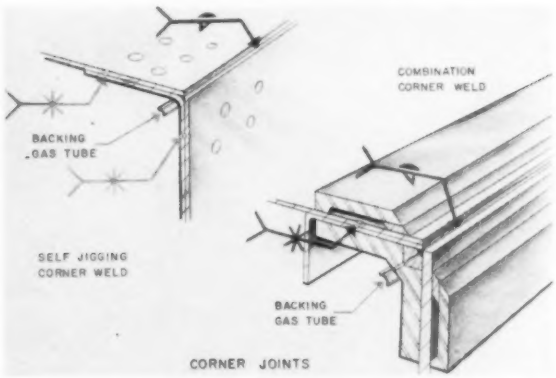


Fig. 10 Self-jigging and combination corner welds

hand illustration). The self-jigging corner weld contains a spot-welded titanium backing strip. Inert gas is directed into the void between the backing strip and the joint during welding. This joint requires little tooling, but often the backing strip must be carried along in the airframe as excess weight.

Two different methods of joining a thick to a thin section are shown in Fig. 11. The weld in which the thin section overlaps the thick section (left hand illustration) requires no backing gas and is partially self-jigging. However, the sections must be tightly clamped and tack welded. This insures a close fit between the mating joint surfaces and prevents a void where air could enter and contaminate the weld metal. This type of weld should be used only when the loading is pure shear. Bending stress on the notch at the root of the weld can cause failure at relatively small loads. A butt weld should be used to join a thick to thin

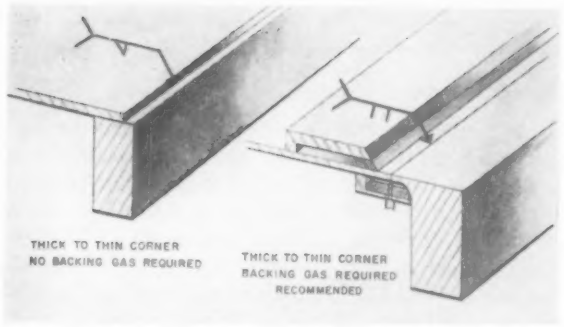


Fig. 11 Corner welds joining thick to thin sections

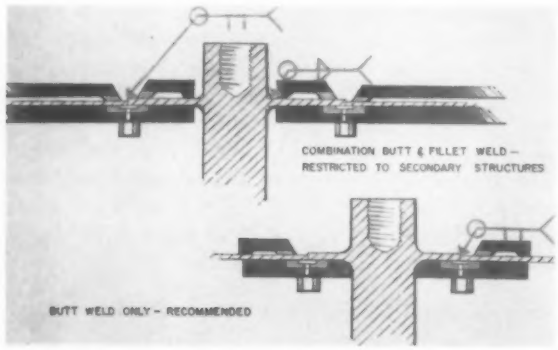


Fig. 12 Attach fittings

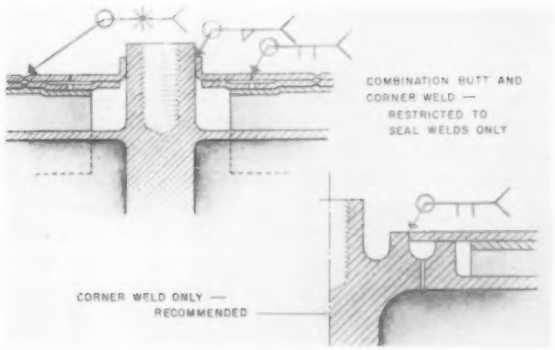


Fig. 13 Attach fittings

corner subjected to bending, as shown in the right hand illustration of Fig. 11. This arrangement requires jigging and backing gas.

"Attach Fittings"

"Attach fitting" joints can be made with various welds or combinations of welds, as illustrated in Figs. 12 and 13. Figure 12 shows a fitting with a combination butt weld and fillet weld (left hand illustration), and a fitting with a butt weld only (right hand illustration). The fillet weld used in combination with a butt weld restricts the former fitting to use as a secondary* joint, but it does reduce the amount of machining required. The fitting with the butt weld only is recommended.

* Primary and secondary joints are defined under "Specific Joint Design Recommendations."

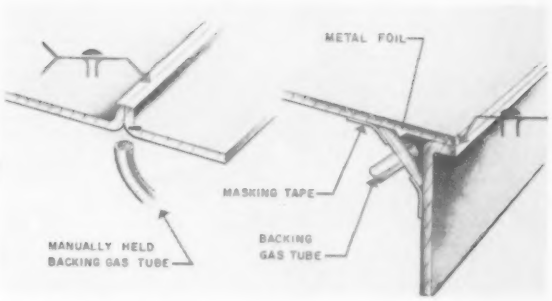


Fig. 14 Flange joints

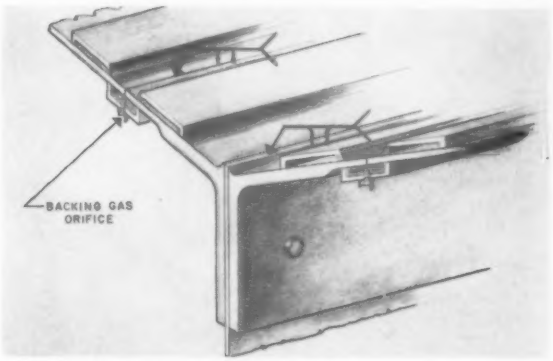


Fig. 15 Extruded shapes used to join three sheet-metal sections

Figure 13 shows a fitting using a corner weld only (right hand illustration), and a fitting using a spot-welded backing strip and a corner and butt weld (left hand illustration). The fitting using a corner weld only is partially self-jigging and requires no backing gas fixture. It must however, contain entry and discharge ports for backing gas. The combination spot corner, and butt weld has the advantage of being completely self-jigging, but its use is restricted to seal welds. Warpage of the backing strip during welding often makes good joint alignment difficult to maintain and results in air leakage at the bottom side of the weld.

Flange Joints

Flange joints have some advantages over butt and corner joints, but they are generally third in preference to the latter two. Figure 14 illustrates two types of flange joints with a different method of applying backing gas for each. Because these joints are easy to clamp, jigging is not usually required. Welds on this type of joint usually result in less warpage than welds made on butt joints. The small radius required at the flange sometimes prevents the use of these joints.

Special Joints

Special joints, when made of material of sufficient thickness to prevent the underside from reaching a temperature in excess of 1000° F, require neither jigging, backing gas, nor the addition of filler material. Figures 15 and 16 show joints of this type. Also

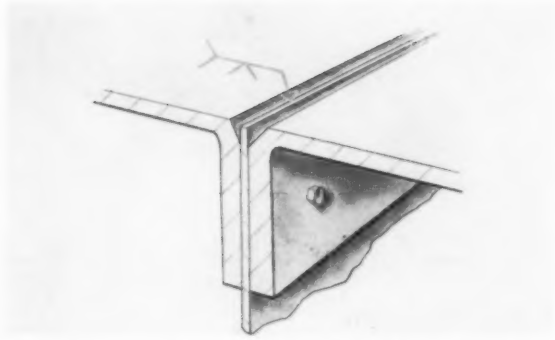


Fig. 16 Extruded shapes used to join thick to thin sections

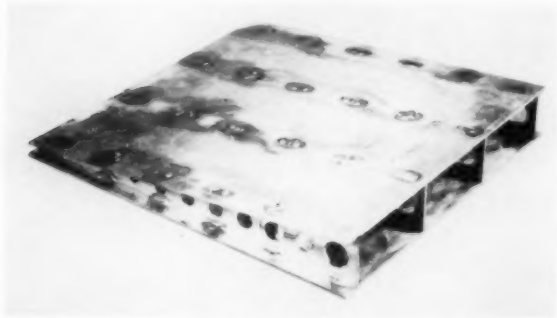


Fig. 17 Test section with intersecting ribs slot welded to top and bottom skins

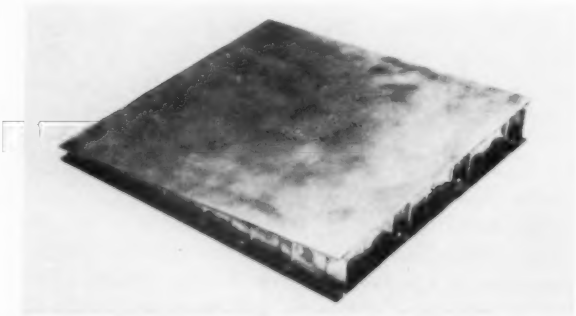


Fig. 18 Test section after machining to simulate the aerodynamic surface of an aircraft component

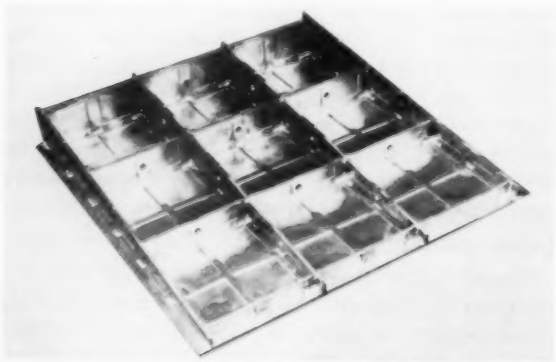


Fig. 19 Test section chemically etched before welding

the joints illustrate the use of extruded shapes to join three sheet metal sections.

Special Types of Construction

An interesting type of construction which has been successfully tested is shown in Fig. 17. Intersecting ribs are tungsten-arc welded directly to skin sections. In this particular test component, the ribs were slot welded to both the top and bottom skins. Another component was made by fillet welding the ribs to the bottom and slot welding them to the top skin. A third was made by inert-arc-spot welding the ribs to the skins.

Figure 18 shows a test section machined after welding to simulate the aerodynamic surface of an aircraft component.

Chemical etching can be used to save weight on a welded structure with a minimum loss in stiffness. Figure 19 illustrates a test section on which both skins and ribs were chemically etched before welding to produce a part with a high rigidity at low weight. The greater cross section at the unetched weld land also permits the fabrication of structures which would be extremely difficult to weld in gages equal to the etched cross section in thickness.

Specific Joint Design Recommendations

The data which follows illustrate all of the common joints used in aircraft work and present specific recommendations for their use with titanium. These data are not intended to be hard and fast rules, but guides of recommended practice.

Figure 20 gives specific recommendations on the design of butt and flange joints. Primary and secondary joints are defined respectively as those joints whose failure will or will not cause serious damage to the aircraft. "C" is the clearance required to provide access for tooling, or adequate heat distribution, or both. Because of the severe notch effect at the weld root, the secondary flange joint may not be used where the root is in tension. It may be used for such structures as low-pressure air ducts, etc. The 2t bend radius required for primary flange joints is difficult to form. This limits the use of these joints to a very few alloys of titanium.

Lap joints are not recommended because of the eccentricity of the loading on the joint; because of the severe stress riser produced at the intersection of the overlapping sections with the weld bead; and because air entrapped between the overlapping sections can cause contamination.

Figure 21 covers corner and tee joints. In corner joints, as in the flange joints illustrated in Fig. 20, the secondary flange joint is restricted to applications where the loading does not place the weld root in tension. Limited use only should be made of the burn-down-type tee joint. It is not generally recommended because of difficulty in maintaining joint alignment during welding. If sufficient care is taken, however, it may sometimes be used to advantage. The fillet-type tee joint may be used when backing gas can be

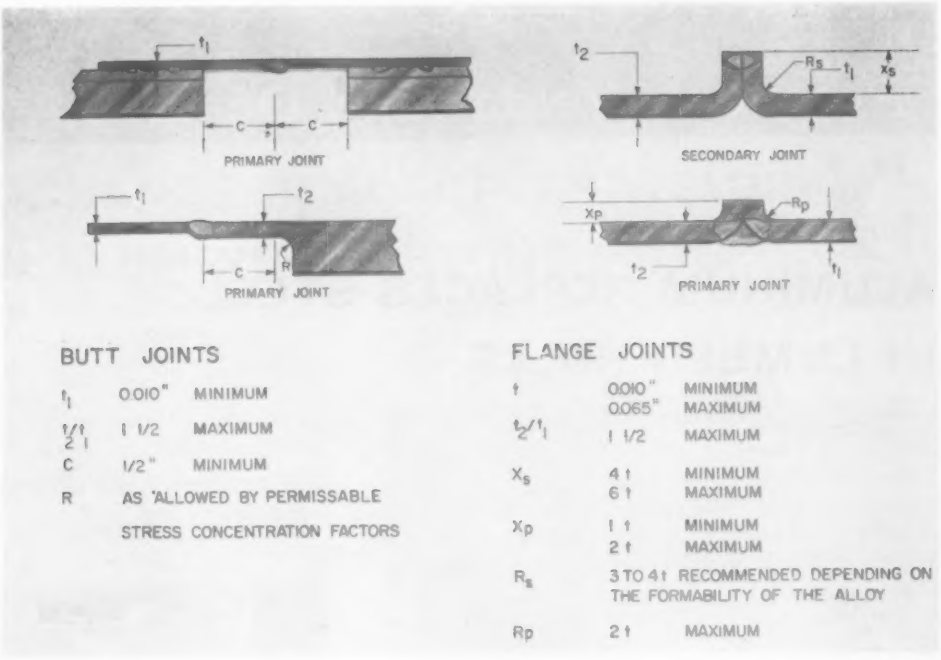


Fig. 20 Design recommendations on butt and flange joints

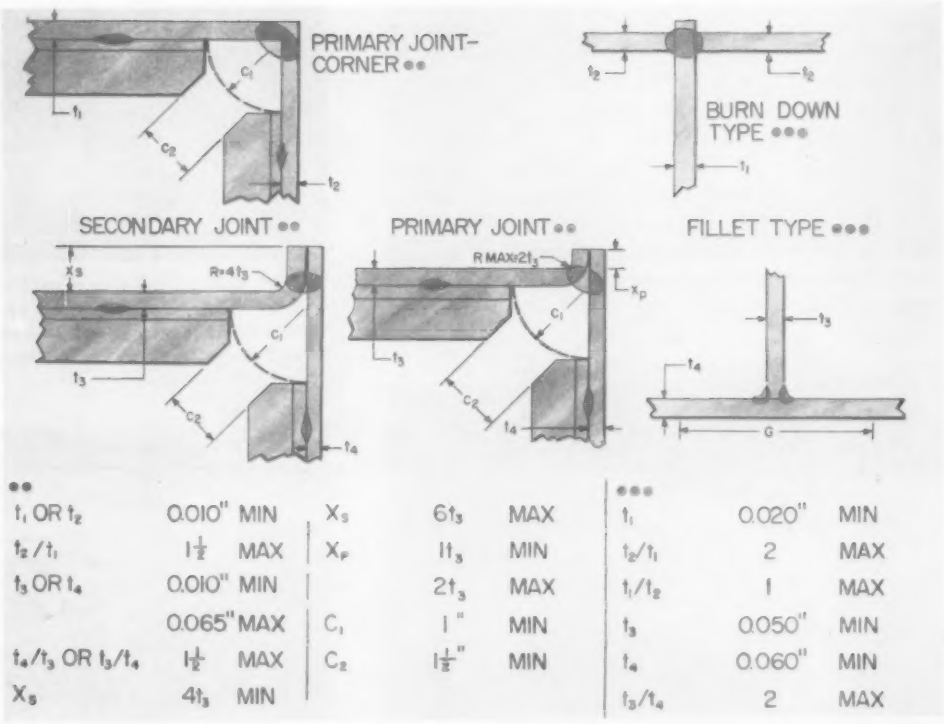


Fig. 21 Design recommendations on corner and tee joints

supplied to the area marked "G" in Fig. 21. This joint usually results in pronounced distortion in welding the thinner gages.

Summary

Strength-weight properties of titanium weldments are generally superior to strength-weight properties of weldments of other metals.

Good weldments of titanium can be produced if correct joint design, choice of alloy, tooling and welding techniques are employed. Accessibility should be provided for both sides of the joint even after final assembly.

Preweld joint preparation is the most important factor in controlling the X-ray quality weldments.

ALUMINUM REPLACES STEEL IN LUMBER ROLLS

Reduction in weight and increase in pay-load capacity has resulted from replacing steel with aluminum in the fabrication of lumber rolls for transport trucks and trailers at the H. B. Rubens Welding and Machine Shop, Sacramento, Calif.

Aluminum rolls provide a weight reduction over steel of approximately 3500 lb per set. In cases where truckers had used extra-heavy steel rolls designed to stand extra wear, the aluminum rolls offer even greater weight reductions.

Indications are that the aluminum rolls wear better than steel rolls because of their greater flexibility and a tendency to maintain alignment under heavy loads. The first set of aluminum rolls was put in service in late 1954 and is still in excellent condition. Users are now installing them on additional trucks and trailers.

In the argon-shielded fabrication, the manufacturer uses a portable manual gas-shielded metal-arc welding outfit with drawn aluminum rod. This rod has a lower melting point and wider solidification range than pure aluminum or any of its alloys and also contracts less during cooling.

Based on a story by the Linde Air Products Co., New York, N. Y.

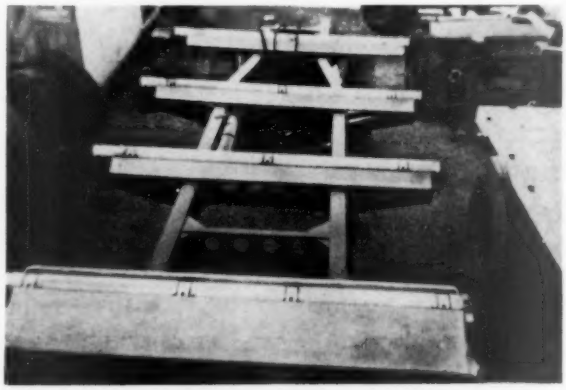


Fig. 2 With all welding completed, the roll assembly consists of slope sheets, bottom, end sheets, bearings and rolls. With the exception of the rolls, all material is formed from flat sheet and welded in the shop

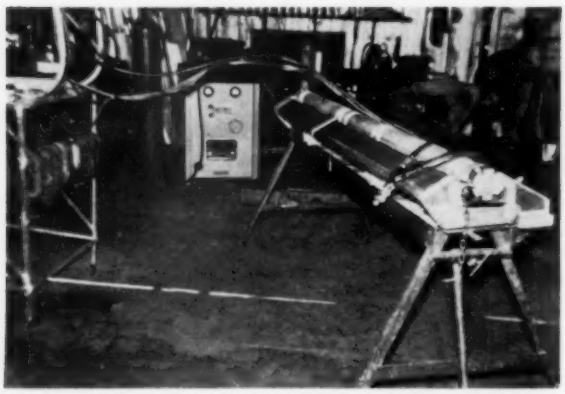


Fig. 1 Tightly clamped, the aluminum lumber rolls are ready to be welded; the manual gas-shielded metal-arc welding torch is shown on top of the welding table

Fig. 3 Installed on a trailer, the light aluminum rolls increase payload capacity by providing a weight reduction over steel of approximately 3500 lb.

PROCESS CHANGE QUADRUPLES WELDING SPEED ON ALUMINUM PISTONS

BY S. L. SULLIVAN AND J. A. GOWEN

Aluminum pistons for diesel locomotives must be designed in such a way as to provide maximum durability because of the rigorous "firing chamber" conditions of their use.

A new high in efficiency on this problem has been achieved by ALCO Products, Inc., Schenectady, N. Y., through coordination of design, material specification, and application of the gas-shielded metal-arc welding process (see Figs. 1 and 2).

The aluminum piston, measuring 9 in. in diameter and 12 1/4 in. high, is designed to receive a ring carrier over the upper third of the piston. The carrier ring, heated to 400° F, is placed over the main body of the piston, then cools, resulting in a shrink fit.

The use of a carrier ring means that ring grooves are not cut into the piston itself but are in the ring carrier, a part which can be removed for repairs and put back on the main body of the piston for further service.

The piston itself is a forging. The ring carrier is cast aluminum with a nickel-iron ring cast into it to reduce wear. Originally, the ring carriers were forged and the welding of the carrier to the main body of the piston was accomplished by the gas-shielded tungsten-arc

S. L. Sullivan is Technical Supervisor and **J. A. Gowen** is Process Representative, Air Reduction Sales Co., Metropolitan District, New York.

Fig. 2 3/8-in. deep bevel groove before welding

Fig. 1 Carrier ring, heated to 400° F, placed over piston body

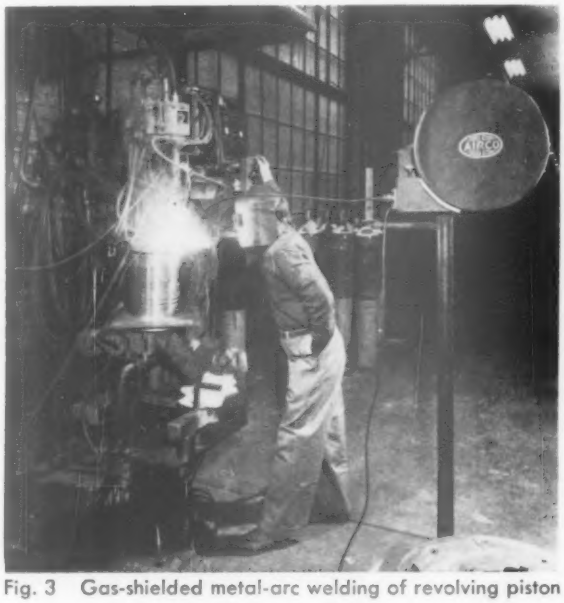


Fig. 3 Gas-shielded metal-arc welding of revolving piston

Fig. 4 Completed circumferential welds ready for machining

process. The 22-in. circumferential seam was welded in $4\frac{1}{2}$ min.

With the use of cast-aluminum ring carriers, it became necessary to reduce heat input substantially in order to avoid cracking. As a result, the circumferential joint was redesigned into a $\frac{3}{8}$-in. deep bevel groove and a fully automatic gas-shielded metal-arc welding setup was installed making use of two filler wires—one hot, carrying welding current, and one cold, with no welding current. The cold wire comes in at an angle while the hot wire comes from the nozzle of the welding head.

The inherent deposition speed of the gas-shielded

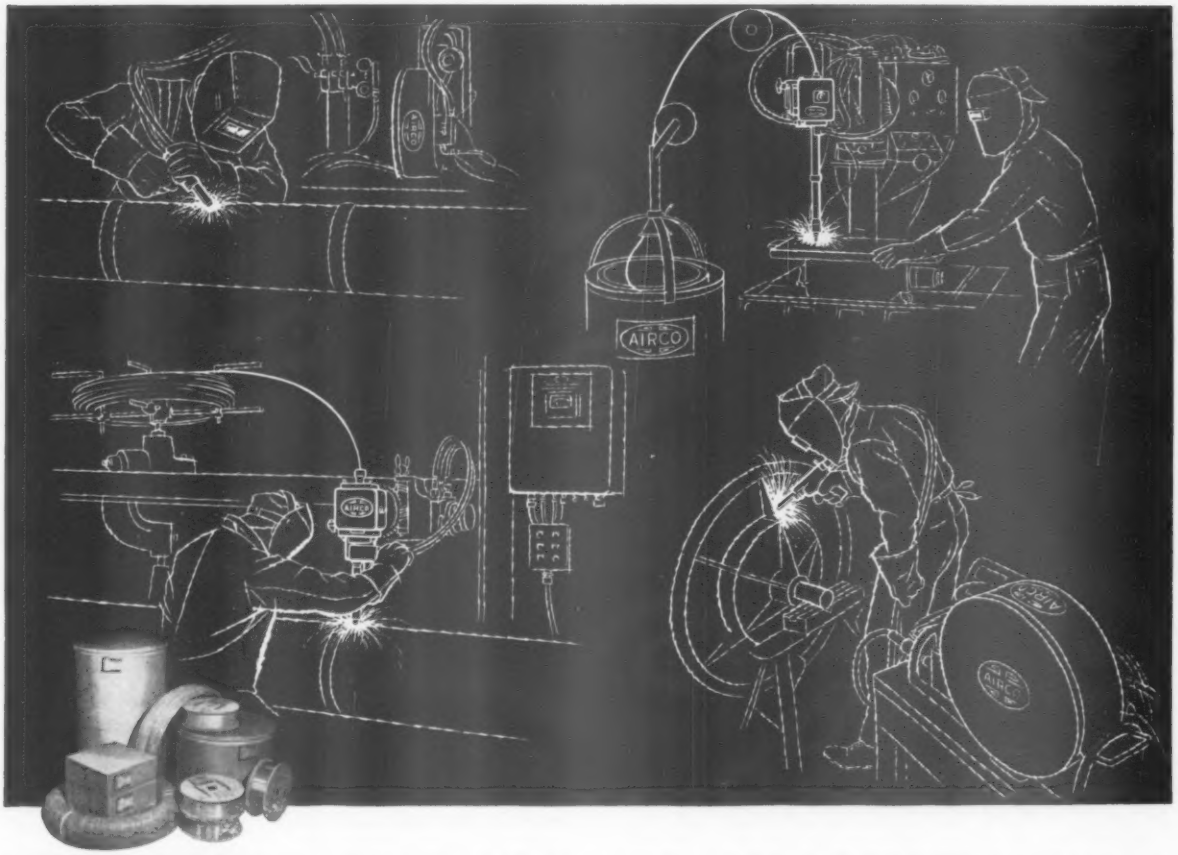
Fig. 5 Piston placed in diesel locomotive engine frame

metal-arc process, plus the use of the auxiliary wire feeder, enabled the manufacturer to build up the 22-in. circumferential seam in one revolution of the piston at a speed of 22 ipm. Thus the welding time was reduced from more than 4 min to 1 min.

Even more important than fast production, the welding speed reduced heat input per inch of weld to a minimum and eliminated cracking. The welding takes place at 300° F with a 75–25 mixture of helium and argon providing the shielding.

Tops in the Industry!

The Welding Journal is the world's most authoritative welding and allied process magazine; it has fully 2½ times the editorial content of any competing magazine; it is unequalled in coverage of welding engineering, research and application. If you have a product for the welding or allied industries, the Journal's pages will reach your market!



THE WIDEST SELECTION OF AIRCOMATIC® WIRE

for any kind of inert gas welding

Successful Aircomatic welding and Heliwelding (where filler metal is required) depend on using the correct wire. Airco can supply the widest variety of wire types and diameters — all specifically designed for use with these inert gas shielded welding processes. All Aircomatic wires meet rigidly controlled specifications as to chemical analysis, surface finish, purity, cast and packaging.

Pure . . . properly cast . . . level wound

Aircomatic Aluminum Welding Wires. New Type A finish available for all high-quality work where X-ray standards must be maintained . . . scrupulously clean . . . bright finish . . . properly wound . . . smooth surface assures trouble-free feeding.

Aircomatic Stainless Steel Welding Wires . . . excellent corrosion resistance . . . good tensile, ductility and impact properties . . . use to weld ordinary joints, apply stainless linings, build-up stainless overlays and join stainless overlays and join stainless clad materials.

Aircomatic Copper and Copper Base Alloy Welding Wires. Use to assemble copper bus bars . . . fabricate copper or bronze vats . . . build-up worn propellers, piston and valve parts . . . available in both solid and stranded types.

Aircomatic Steel Welding Wires. Three grades available for welding mild steel, armor plate and for overlays and welding hardenable steels.

Nickel base, magnesium, and titanium wires are supplied as specials. Consult your nearest Airco Office or Authorized Airco Dealer for complete information.

AT THE FRONTIERS OF welding PROGRESS YOU'LL FIND . . .

AIR REDUCTION PRODUCT

VISIT OUR BOOTH 334 — WELDING SHOW

APRIL 9-11, 1957 · PHILADELPHIA, PA.

AIRCO®

Offices and dealers in most principal cities

AIR REDUCTION SALES COMPANY

A division of Air Reduction Company, Incorporated
150 East 42nd Street, New York 17, N. Y.

On the west coast — Air Reduction Pacific Company

Internationally — Airco Company International

In Cuba — Cuban Air Products Corporation

In Canada — Air Reduction Canada Limited

Products of the divisions of Air Reduction Company, Incorporated, include: **AIRCO** — industrial gases, welding and cutting equipment, and acetylenic chemicals • **PURECO** — carbon dioxide — gaseous, liquid, solid ("DRY-ICE") • **OHIO** — medical gases and hospital equipment • **NATIONAL CARBIDE** — pipeline acetylene and calcium carbide • **COLTON** — polyvinyl acetate, alcohols, and other synthetic resins.

WELDED TRUCK TANK PREVENTS LIQUID PROPANE SPILLAGE

More and more, welded structures, shapes and tanks are winning the battle cry for added safety. This point was graphically illustrated recently when a truck tanker, fully loaded with highly inflammable liquid propane gas and stored under a pressure of 200 psi, crashed into a bridge abutment. Although the undercarriage of the carrier was totally demolished (see Fig. 1), there were no leaks in the welded steel tank itself nor was a drop of liquid propane lost through other causes. The tank had thus proven itself to be virtually indestructible.

This liquid carrier tank was manufactured by the Mosher Steel Co. of Houston, Tex. and fabricated from T-1 steel. In welding the steel plate by the submerged-arc method, the fabricator utilized a 0.5Cr-0.5Ni-0.25Mo automatic welding wire. The T-1 steel has a tensile strength of 105/130,000 psi and an elongation of 15–20%, and is comparable to and compatible with the 115,000 psi strength and 14% elongation of the welding wire used.

Before repairing the truck's undercarriage, the tank was sandblasted clean and thoroughly inspected by magnetic particle process. No cracks could be found in either the T-1 steel plate nor at any of the welds.

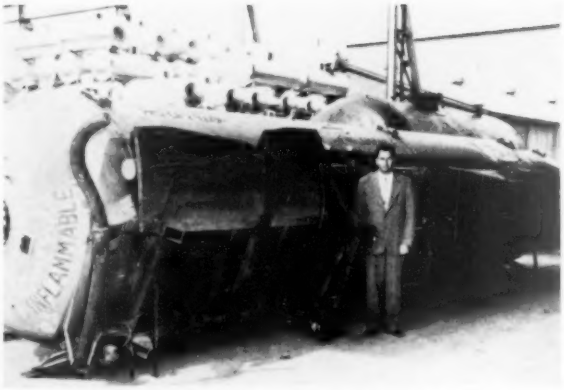


Fig. 1 The carrier tank, turned on its side, has just passed a rigid magnetic particle examination; no cracks or flaws were detected in the plate or at the welds

Based on a story by the American Chain & Cable Co., Inc., Bridgeport, Conn.

HEAT TRANSFER AND CORROSION PROBLEMS SOLVED WITH SPRAYED METALS

Servel, Inc., Evansville, Ind. uses sprayed aluminum to improve the heat transfer characteristics at key operating areas in gas refrigerating units. The walls of the piping where the heat exchange is to take place are tack-welded together. The joint throughout the pipe lengths is then built up with sprayed aluminum to provide an effective heat transfer "bridge" (see Fig. 1).

The Servel gas refrigerating unit is made up of a series of steel pipes and chambers welded into a single system without moving parts. Corrosion protective coatings are used throughout the unit. However, the welding of the joints unavoidably destroys the coating at these points. They are metallized with pure zinc after fabrication to restore this vital protection and ensure trouble-free operation.

Fig. 1 Voids left by capillary action are here shown being filled in with sprayed aluminum; this solves a heat transfer problem

Based on a story by Metallizing Engineering Co., Inc., Westbury, N. Y.

Lincoln engine welders have

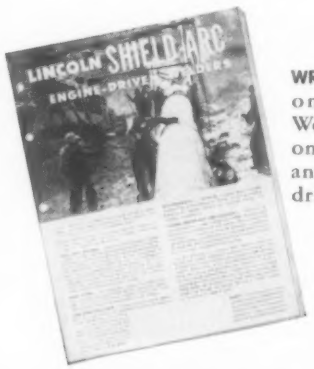
STAMINA

9 out of 10 contractors say Lincoln Shield-Arc's can take it . . . and dish it out

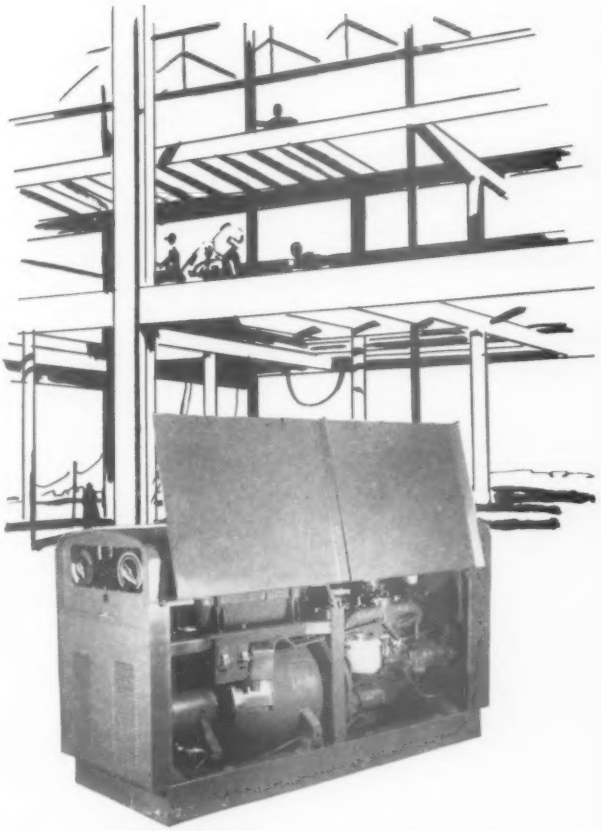
- **SLOW SPEED ENGINES for long life**
- **Heavy-duty, rugged design**
- **Extra overload capacity**
- **Close speed regulation and current control**

Gasoline engine driven models in 200, 300, 400, and 600 amp sizes.

Diesel engine driven models in 250, 300, and 400 amp sizes.



WRITE FOR SPECIFICATIONS on Lincoln Shield-Arc Welders. Bulletin SB-1356 on diesel driven welders and SB-1337 on gasoline driven models.



THE LINCOLN ELECTRIC COMPANY

Dept. 1927, • Cleveland 17, Ohio

The World's Largest Manufacturer of Arc Welding Equipment

ALL-ALUMINUM SHOWER ENCLOSURES FOR PASSENGER LINERS

Two former workhorse freighters will ply the Pacific Ocean as swift, sleek passenger liners following a Cinderella transformation utilizing substantial amounts of lightweight aluminum.

Renamed the *Mariposa* and *Monterey*, the pair of 14,000-ton Oceanic Line ships were rebuilt from cargo hold to bridge by Willamette Iron and Steel. The remodeling operation, first major shipbuilding project in the Northwest since World War II, used aluminum in shower units, stack enclosures, lifeboats, accommodation ladders, non-slip stair tread, and storm rails. Even color-splashed Polynesian symbols, serving as decorative pieces throughout the ships, were fashioned from aluminum.

Each 20-knot luxury liner will sail the sea routes from the West Coast to Australia and New Zealand, carrying 365 first-class passengers. Accommodations and facilities in the $27-million conversions offer the utmost in modern decor and convenience, including 304 all-aluminum shower enclosures made of sheet and extrusions (see Fig. 1).

The shower units for the new liners were fabricated using the inert-gas-shielded metal-arc consumable-electrode welding process. A large aluminum sheet, in alloy 6061, first was formed into a distinctive enclosure shape. The pan and head strip were tack welded in place. Fabrication then was completed quickly by using a rotary jig that eliminated positioning time during welding. After seams on one side were joined, the next side was positioned immediately by revolving the unit in the jig.

Subsequent handling and installation of the shower units aboard the *Mariposa* and *Monterey* were made easier because of weight savings achieved by the use of aluminum.

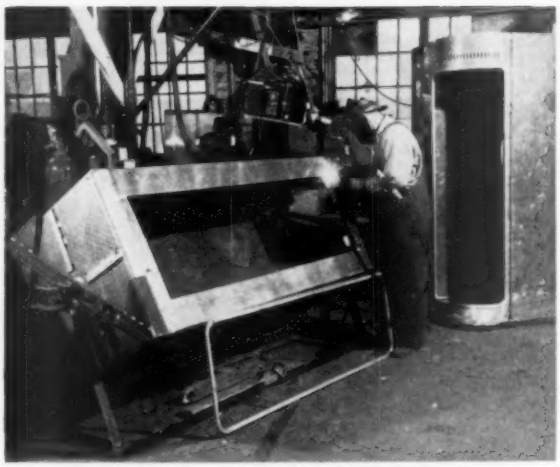


Fig. 1 The gas-shielded metal-arc consumable-electrode welding process was used to fabricate 304 aluminum shower enclosures for installation aboard new luxury liners; use of a special rotary jig eliminated positioning time, and cut total fabricating time required for the shower units

Based on a story by Aluminum Company of America, Pittsburgh, Pa.

Correction:

"Study of Interrupted Welding of Heavy-Wall Steam Pipe"
by I. A. Rohrig, J. O. Smith and E. G. Shifrin

In the February 1957 issue of THE WELDING JOURNAL, *page 128, the "$^3/_4$ in." given in the blurb is incorrect. The full statement should read as follows: "Investigation reveals that 2 $^1/_4$% chromium—1% molybdenum alloy-steel pipe in wall thicknesses up to 3 $^3/_4$ in. can safely be welded with interrupted heat cycles if proper precautions are exercised"*

The Editor

USS TECHNICAL WELDING DATA

1

Recommended practices for welding and gas-cutting USS "T-1" Steel

WELDING. You can metal-arc weld USS "T-1" Steel manually in the same way as hot-rolled structural carbon steels, but be sure to use low-hydrogen electrodes of the E9015-16 to E12015-16 classifications. These electrodes must be kept dry. You also can automatically weld this steel by the submerged-arc process and by the inert-gas-shielded metal-arc process. The "stringer bead" technique is the best to use.

Precautions when welding USS "T-1" Steel:

1. **Do not use cellulose-covered electrodes because of the danger of underbead cracking.**
2. **If the final weldment must be stress-relieved or otherwise heat-treated, do not use electrodes of the Nickel-Molybdenum-Vanadium type.**
3. **In general, do not preheat this steel. If preheating is necessary to improve the properties of the weld metal, don't let the preheat temperature go above 250 degrees F.**
4. **Whether or not you preheat, don't let the interpass temperature go above 250 degrees F.**
5. **Be careful to prevent local overheating if flame gouging is used.**
6. **In submerged-arc welding, don't let the heat input to the base metal be greater than that used with 5/16" diameter manual electrodes.**

GAS-CUTTING. USS "T-1" Steel may be gas-cut as readily as structural carbon steel, using any of the commercial fuel gases now in use. Preheating is not necessary. You can soften the flame-cut edge to facilitate machining, if you desire. If you do, don't let the temperature of the flame-cut edge go above 1150 degrees F. This temperature should be measured by temperature-indicating crayons or other suitable means.

Precaution: Never gas-cut blooms, billets, bars or ingots of USS "T-1" which have not been quenched and tempered. They should be sawed or hot-sheared, or cold-sheared if the size permits.

QUALIFICATION OF WELDERS. In some cases, AWS-ASME Standard Qualification Procedure for testing welding operators is not suitable for USS "T-1" Steel. The standard 3/4"-radius mandrel and guided bend jig force an elongation of about 20% in the extreme metal fiber. Since this is beyond the capacity of the high-yield-strength weld metal deposited by some electrodes used with USS "T-1" Steel, a welding operator should not be disqualified because of weld-metal characteristics not under his control. Consequently, the ASME Boiler Code permits, in certain cases, a larger 1 1/4"-radius mandrel for the qualification test.

REMEMBER THIS: In no other alloy plate steel would you find the combination of properties that "T-1" Steel possesses. Here, in just one steel, you get very high yield strength (90,000 psi minimum), extraordinary toughness, great resistance to impact abrasion, and good high temperature strength. These let you reduce the size of highly stressed parts . . . save weight, reduce the amount of welding required and cut your costs. USS "T-1" Steel is being used in bridge excavating equipment, pressure vessels, towers . . . in equipment that must take heavy abuse in sub-freezing temperatures . . . in equipment that must withstand heavy stresses and impact abrasion at temperatures as high as 600 degrees F.

Write For Complete Information about the application and fabrication of USS "T-1" Steel. United States Steel, Room 5603, 525 William Penn Place, Pittsburgh 30, Pa.

USS "T" CONSTRUCTIONAL ALLOY STEEL

"USS" and "T-1" are registered trademarks.

UNITED STATES STEEL CORPORATION, PITTSBURGH · COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA.
UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS, COAST-TO-COAST
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

UNITED STATES STEEL

See The United States Steel Hour. It's a full-hour TV program presented every other Wednesday evening by United States Steel. Consult your newspaper for time and station.

Society News

Dues and Grades — A Subject of Interest to All AWS Members

During the past twenty years the records of the AMERICAN WELDING SOCIETY show that there have been many recommendations for change in its member grade structure. Upon study, it was generally decided to make no change. Perhaps this was for the best, as during that period we have been able to evaluate a changing pattern within our industry and welding engineering. If one of the previously recommended paths had been chosen, it is possible that a mistake would have been made.

However, the time has now come when the problem must be solved both from the standpoint of member grades classification and the financing therefor. During the past year the SOCIETY's Board of Directors, its Finance Committee and the Special Committee on Member Classes have given considerable time to the study of patterns which might effect satisfactory cures.

Basic Membership

There have been differences in opinion in regard to the basic membership groups; the Associate Member and the Member grades. Some feel that the only difference between these two grades is that the Member is provided with a copy of the Handbook. Others believe that the grade of Member signifies status, and that the Associate Member should strive to attain such a grade and this group feels that the providing of the Handbook to the Member grade represents a dollar value benefit. The first group feels that the Associate Member and the Member grades should be combined into one, that of *Member*.

The decision regarding this problem must be left with the members who vote. However, if one membership grade is adopted, it may be necessary to withdraw the distribution of the WELDING HANDBOOK as a benefit, because of the increased costs involved.

Postgraduate Need

The SOCIETY provides, and subsidizes, a Student grade, which was originally available only to students of recognized engineering colleges. It is now available to students of vocational schools.

Within our membership, there are those who believe that we should have a *Junior* grade of membership, which would be available to the graduate student regardless of his graduate origin, and such priced as low as possible. He would be allowed to hold this grade during those years when he would be getting his feet on the ground, either in industry or in his profession, but would be required to raise his grade at a specific age.

Engineering Recognition

There are many in the SOCIETY who believe that a grade of membership should be provided which recognizes ability of those who have invested their engineering training and experience in the interest of welding. The term of "welding engineer" has been discussed and the grade of "engineer member" has been suggested. However, there does not appear to be universal acceptance of either the industry classification "welding engineer" nor of the member grade classification "engineer member." It does appear that the classification *fellow* covers the requirements and would be supported by all.

Sustained Support

The SOCIETY is frequently called upon to broaden its current activities and to assume new tasks. It has done the best it could with the income available; in fact, it has extended itself into deficit in its effort to satisfy these requests. It is now being called upon to extend its activities in the educational field: trade and vocational schools, in-plant training, technical institutes and universities. It is felt by many that the SOCIETY should be the organization to do this inasmuch as it is the only neutral representative group of all welding phases and interests in this country.

AWS DIRECTORS-AT-LARGE

Term Expires	1957	1958	1959
	R. W. Clark	F. H. Dill	J. H. Blankenbuehler
	J. W. Mortimer	E. D. Peters	G. E. Linnert
	Hal Savage	J. L. Wilson	Gordon Parks
	R. L. Townsend	R. J. Yarrow	F. H. Stevenson

AWS DISTRICT DIRECTORS

District No. 1 • New England	Sidney Low	District No. 7 • West Central	A. F. Chouinard
District No. 2 • Middle Eastern	D. B. Howard	District No. 8 • Midwest	F. G. Singleton
District No. 3 • North Central	C. E. Jackson	District No. 9 • Southwest	P. V. Pennybacker
District No. 4 • Southeast	E. C. Miller	District No. 10 • Western	C. L. Breese
District No. 5 • East Central	Lew Gilbert	District No. 11 • Northwest	C. M. Styer
District No. 6 • Central	Keith Sheren		

OTHER DIRECTORS

Honorary Life Director	C. A. Adams	Junior Past-President	F. L. Plummer
Junior Past President	C. H. Jennings	Junior Past-President	J. H. Humberstone

The SOCIETY early recognized the need for such activity and established a member grade pattern which, it was hoped, would support it: *Sustaining* membership. However, this pattern has not produced the income for performing the task. A new pattern will have to be created, one which will allow both individuals and organizations to contribute adequately to the support of these important activities.

The Means

No person can buy today other than a small portion of what his dollar bought in 1940. The same applies to our SOCIETY. It must purchase all that it buys at the same market price that the individual and the industry must meet. Nevertheless, the SOCIETY has endeavored to maintain its member dues at the lowest possible figure. The fact is that up until 1931 the dues for a member were $20.00. Each year the SOCIETY spends some $47,000 on its technical activities alone and, in direct return receives but $13,000 for the sale of the tangible items—codes, standards and specifications. However, this is a worth-while investment, because they have contributed notably to the improvement and to the increased use of welding, as well as broadened the knowledge of welding engineering, thereby benefiting every one in the industry.

As previously stated, the SOCIETY subsidizes the Student membership, giving all Student members THE WELDING JOURNAL each month; the cost of this alone is greater than the student's dues. In the early 1920's the SOCIETY's membership dues accounted for 90% of its income; today, they account for less than 45%. It must earn the remaining 55%.

Some feel that the dollar return the SOCIETY receives from its Welding Show must certainly provide it greater income. This is true, but the SOCIETY also has to assume a much greater expense and must support all its other convention activities out of the exposition returns. In this fifth year, it is hoped that the SOCIETY will break even on its national annual convention activities. If the SOCIETY had not entered the exposition field, it would not have been able to continue giving its members their current benefits without raising the dues quite some time ago.

Conclusion

Our SOCIETY has now reached a point where facts must be faced and means found to support the way. All inherent problems have been given consideration by its Board of Directors and the committees concerned. It is expected that, within one or two months, the result of their deliberations will be published in THE WELDING JOURNAL and, in customary time, a ballot will be presented to the membership for vote.

The SOCIETY belongs to you—its members. It can do only what you want and allow it to do. If you wish to accomplish those things vital to you and to your industry, you can provide it with the power to do so. It is your SOCIETY—the answer is yours.

SANTA CLARA VALLEY SECTION TO HOLD EDUCATIONAL LECTURE SERIES

The *Santa Clara Valley* Section plans to hold an Educational Lecture Series on the topic of Welding Metallurgy. The series of three lectures will be given by Dr. Robert A. Huggins, Asst. Prof. of Metallurgy at Stanford University.

There will be a registration for these lectures, which are to be held in the Engineering Auditorium of San Jose State College, San Jose, California on the evenings of April 23, 24 and 25.

Additional information may be had by writing to Mr. Ralph Parkman, Education Chairman, Santa Clara Valley Section, c/o Engineering Dept., San Jose State College, San Jose, Calif.

AMERICAN WELDING SOCIETY DIRECTORS VISIT A. O. SMITH PLANT

On the occasion of the January 29th meeting of the Board of Directors in Milwaukee, the group visited the A. O. Smith Corp. plant. Above, R. J. Keller, Assistant Director, Welding Research, A. O. Smith Corp., is shown greeting the assembled guests. They are: front row (*left to right*), A. E. Pearson, E. C. Miller, First Vice-President C. P. Sander, P. G. Parks, K. Sheren, R. J. Yarrow, F. G. Singleton and R. W. Clark; second row (*left to right*), D. B. Howard, C. E. Jackson, E. D. Peters, Second Vice-President G. O. Hoglund, F. J. Mooney, A. F. Chouinard and G. E. Linnert; third row, (*left to right*), J. H. Blankenbuehler, F. H. Dill and President J. J. Chyle.

Transport tank begins to take shape, as butt joints are welded to form outer shell. Heil Company is one of the top producers of aluminum transport tanks.

Switch to Fillerarc* equipment boosts

PRODUCTION RISE ATTRIBUTED TO FASTER WELDING, FEWER REJECTS

Building aluminum transport tanks that must withstand pressures of 34,000 pounds per square inch requires welds that are near-perfect . . . leakproof.

At the Heil Company, Milwaukee, Wisconsin strict tests show that more tanks welded with General Electric automatic and semi-automatic welders are leak-free than those welded with any other equipment they have used or tested.

Rejects have been cut so much since the switchover to General Electric Fillerarc equipment that production has jumped 35%.

Increased speed of welding is also helping to boost production at Heil. The automatic current regulation and constant arc length features of the equipment enable weldors to set the generators once and then forget about them . . . even if they change wire speed in the middle of a job.

This saves the time previously spent crawling in and out of the tank bodies to change settings.

WIRE PULLING FEATURE REDUCES JAMMING

Weldors are enthusiastic over the fact that the Fillerarc gun pulls the wire to the work instead of pushing it. Using fine $\frac{1}{16}$" aluminum wire, Heil had experienced considerable kinking with previous equipment. According to Harold Woda, weldor-fitter, "We couldn't weld an hour straight without it jamming up. Now, using the Fillerarc gun, the wire never jams," he says.

Bill Dyble, supervisor of welding engineering and research for Heil, is pleased with the constant arc length feature of Fillerarc welders. "Constant arc voltage prevents burnback," he says. "Before switching to Fillerarc welders some of our operators spent as much as two hours a day overhauling their torches."

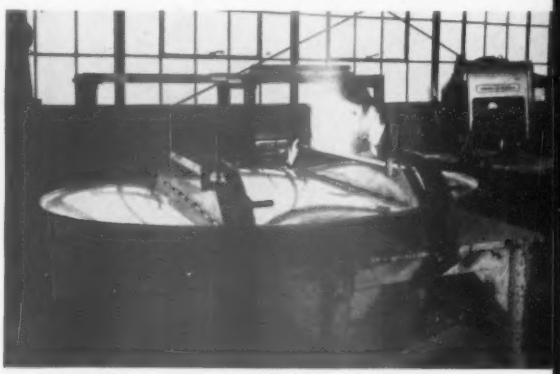
*Reg. trademark of General Electric

GENERAL ELECTRIC

FIRST STEP IN TANK PRODUCTION is joining sheets of 5/32" thick aluminum alloy, type 5154. Automatic Fillerarc welding is used here. Inset shows sample of weld obtained.

COMPARTMENT SECTIONS SECURED with semi-automatic Fillerarc welders. Wire drive, argon gas cylinder are on cart for easy portability.

WELDOR ADJUSTS WIRE SPEED with remote-control unit . . . no need to crawl out of tank. Automatic current and arc-length features of equipment take care of the rest.



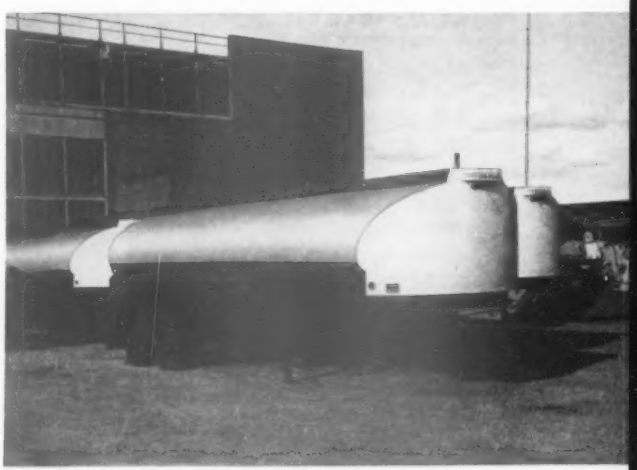
COMPARTMENT SEPARATORS ARE WELDED on special holding fixture. Wire pulling Fillerarc gun reduces jamming, cuts maintenance time.

tank production 35% at Heil Company

Fillerarc welding is General Electric's consumable-electrode, gas-shielded process for either semi-automatic or automatic welding. Now, using carbon dioxide gas as the shielding agent, the Fillerarc system is ideal for mild steel applications. It is fast, economical, clean (no messy flux to bother with), AND, the welds obtained are sound, weld after weld.

For a demonstration of the Fillerarc process, contact your nearby General Electric Welding Distributor. He is listed in the yellow pages of the telephone book. Or, write for more information to Section 713-8, General Electric Company, Schenectady, New York.

Be sure and see the General Electric display at the American Welding Society show, April 9–11, Convention Hall, Philadelphia, Pennsylvania, booth No. 322.



FINISHED PRODUCT—an aluminum petroleum tank, fabricated with Fillerarc welding equipment. Capacities of these tanks run from 3,000 to 9,000 gallons.

For the tough job of fabricating the steel framework of the Recreation Bowling Center of Houston, Texas, Southern Steel Erectors uses General Electric engine-driven welders. Low maintenance features impress company owner, Mr. R. O. Matthews.

Contractor picks General Electric welders for his tough outdoor construction jobs

Southern Steel Erectors, a Houston, Texas contractor, demands welding equipment that is tough enough to withstand the punishment found in outdoor steel framework construction.

No wonder, then, that R. O. Matthews, owner of the firm, now specifies General Electric engine-driven welders for his welding jobs.

He finds that with General Electric equipment, repairs no longer cause cost-consuming downtime for his company. Some of the reasons for this are:

- **Extra-heavy-gage metal construction minimizes accidental damage.**
- **No exciter is required. A potential trouble spot is eliminated.**
- **Constant-pressure brush springs and pre-set brush holders require no adjustment—are factory set.**
- **Pre-lubricated bearings all but eliminate bearing maintenance.**
- **Steel driving disk holds generator exactly in line with engine shaft—has no expendable parts.**

Weldor E. D. Keck says that during his 15 years as a weldor, using nearly every make of equipment, he has found the new General Electric engine-driven welders are the easiest to use and produce the best welds.

Mr. Matthews also says, "This G-E engine-drive has more power than other welders, and we save on fuel, too. We use only one gallon of gas per hour. Also, I like its adaptability to a wide range of rod sizes."

Weldor E. D. Keck says, "I've found in my 15 years as a weldor that the new G-E engine drive gives you a better weld—easier, because there is no fluctuation. All you do is set the machine and it will remain true and constant."

General Electric's new line includes three sturdy ratings, 200, 300, and 400 amperes. For more information contact your nearest General Electric Welding Distributor, listed in the yellow pages of the telephone book. Or, write section 714-6, General Electric Company, Schenectady, New York.

Don't miss the General Electric display at the AWS Welding show April 9-11 at Convention Hall in Philadelphia. The display will be in booth No. 322.

GENERAL ELECTRIC

EAC DOINGS

One Solution to Manpower "Welding Technology"

by Roy B. McCauley

The welding field has proved to most everyone who participates in it that the best final product or design is the result of a number of talents. When all of the people concerned can contribute to a final analysis and a broadly trained coordinator can properly weigh each suggestion, revision is minimized. This is true whether the product is a complicated weldment or an educational program.

The Educational Activities Committee of the AMERICAN WELDING SOCIETY is such a group. In their deliberations they unearthed a general ignorance of an educational program which has a tremendous potential for the welding field. This is the program of the *technical institute*. The program is the natural result of three groups getting together and examining their mutual problems. These three are, namely: the employer, the student and the teacher.

First an examination of the employers' problems shows that his personnel are tremendously understaffed. All of his technical men are loaded with engineering analysis, engineering detail, test work, production blocks and an endless amount of paper work. Not only does he need more engineers but he needs a greater number of men with an intermediate technical training. That training would be intermediate between the skilled craftsman and the engineer. This person would be trained not only to relieve the engineer of engineering detail but possibly to make him better able to cope with it. Government and industrial leaders estimate that a minimum of from three to five technologists to each engineer would most efficiently expedite U. S. industrial staffs. This program has been analyzed in the shop and in the research laboratory and a similar level of training would serve most effectively. Simply, "Each chief needs more Indians."

The *technical institute* has a tremendous student appeal. The present age of the thermal barrier, nuclear fission, radar and ultrasonic testing has created a strong interest in things technical. However education, environment or social conditions have not given all students both a facility for mathematics and the interest to plow through technical theory. Many young people do not, or are not able to, muster the force necessary to master courses in high school required for engineering college entrance. These young folks seem to be more interested in doing, than in finding out more about how-to-do. They want to be productive sooner and at a different technical level than either the engineer or the craftsman. Publicity-wise, the student area is one in which more work is needed to bring this opportunity to a greater number of students.

Special interests become evident in both junior high and high school. The educators also notice this new strata of technical interest. Some students evidence interest in trades and crafts, some in technical-level technology and others in engineering and research. Educational advisors challenge the interests of these young citizens and then direct them to the level that their response indicates. Tremendous satisfactions and future are ahead for the person striving in any of these areas. Engineering educators have noted with alarm the many misdirected youngsters who desire to become "an engineer" but are sadly disappointed when they learn of the depth of background needed in mathematics, physics, mechanics and chemistry. Both this frustrated student and technology have suffered if he rejects his technical bend because the engineering strata is not in his interests.

As a result of this group thinking, the *technical institute* was born. Basically, the program is of a one- or two-year duration. The one-year program is called the technical program and successful completion earns the diploma of a designated technician, such as a welding technician. The second year is known as an associate curriculum and its diploma title is an associate designated, such as associate in welding. The associate program is directed at the individual who would become an engineering aid to the welding engineer. This man, with basic instruction, would be able to, for example, develop welding procedures or do detail designing in a product design. The welding technician is a less skilled person and could do procedure testing and check design dimensions and calculations. These jobs indicate to some extent the two different types of training. Some institutions add these curricula to a one-year trade school program of welding and, as a result, require two and three years for their welding technician and associate in welding training, respectively. However, this procedure does not seem to be the present trend. Today both the educator and employer prefer to separate the craft and technician in training and task.

The associate training program varies widely from one area to another depending upon the needs of the particular locality. Below is a sample curriculum to give some idea of the level of training. This curriculum is not particularly representative or typical, but represents the basic thinking of educators in this field. Here one can see that the technical Institute graduate may be expected to be a welder and maintenance person as well as one versed in the fundamentals of his area of training.

A Sample Program of the Associate in Welding

Subject	*Time, %*
Welding	30
Metallurgy	10
Electricity and Physics	10
Design and Mechanics	10
Other Shops	10
Processes	5
Procedures	5
Mathematics	5
English and Business	5
Drawing	5
Chemistry	5

This program can also be improved in depth in stature with the interest and cooperation of the members of the AMERICAN WELDING SOCIETY. The Committee G of the Educational Activities Committee is already surveying this educational program as an important facet in welding industry manpower. This is just another of the hidden benefits to the welding field by its own SOCIETY.

PLAN NOW
for
1958 AWS NATIONAL SPRING MEETING
APRIL 14–18
ST. LOUIS, MO.

Professor Roy B. McCauley is coordinator for Subcommittees on College Training and Technical Institutes, AWS Educational Activities Committee; chairman, Department of Welding Engineering, Ohio State University, Columbus, Ohio.

Third Midwest Welding Conference Featured by Timely Papers

Stainless steel weldments under service conditions reveal relatively few failures, the third annual Midwest Welding Conference was told in Chicago.

The speaker was G. E. Linnert, 1956 AMERICAN WELDING SOCIETY Adams Lecturer and research welding metallurgist at Armco Steel Corp. laboratories.

He said performed data showed that a substantial percentage of service failures are caused by conditions having little or no connection with the welding performed on the article.

The conference, sponsored jointly by Armour Research Foundation of Illinois Institute of Technology and the Chicago section of the AMERICAN WELDING SOCIETY, was attended by 225 industry representatives.

Linnert's paper, entitled "Trouble-Free Service from Stainless Steel Weldments," was one of 12 presented during the two-day conference, January 30-31.

The importance of cleanliness in a plant that fabricates aluminum of thicknesses such as are required in tank car construction was emphasized by O. H. Kuhlke, welding engineer, General American Transportation Corp.

Discussing high-frequency resistance welding, Wallace C. Rudd, vice-president, New Rochelle Tool Corp., cited a number of advantages of this method over conventional methods. Among them, he mentioned higher speeds, a smaller heat-affected zone, a relative unimportance of welding edge condition, and versatility.

"Pressure Welding" was the subject of a paper by Arnold P. Lage, supervisor, welding group, Menasco Manufacturing Co. He described the role of pressure welding in the fabrication of aircraft landing gear assemblies at the Menasco plant.

Three papers were devoted to the use of welding in the nuclear reactor field. F. V. Daly, welding supervisor, Newport News Shipbuilding and Drydock Co., described the methods used in producing the components and the welding techniques followed in constructing the first zirconium vessel for a nuclear reactor.

P. Patriarca, metallurgist at Oak Ridge, presented a description of the techniques, procedures and equipment associated with the process of high-temperature, dry-hydrogen brazing. Metallurgical aspects of importance in the development of brazing alloys were covered, as well as the preparation of laboratory test specimens.

Welding of reactor components as done by Foster Wheeler Corp. was discussed by Norman Block, consulting metallurgist of the company.

Research and development work performed to evaluate large stud welding technical problems was covered by R. C. Singleton, vice-president, engineering, Nelson Stud Welding. He also described some typical commercial applications for large studs.

Present-day applications of inert-gas welding, and probable future usages of the process, were outlined by J. E. Dato, assistant manager, welding, Linde Air Products Co. He described the use of inert shielding gases through the torch, as well as a backing medium, for stainless steel and other alloy weldments. Mixtures of argon with other gases were discusssed.

Drawing on experience at Bendix Aviation Corp. in salvaging by welding steel landing gear components and aluminum fuel device parts, J. C. Weis explained the manner of deciding whether a weld repair is feasible. He also discussed the means of maintaining proper control of weld repairs so that the end result is compatible with the decision to repair by welding.

E. E. Williams, special engineer, Factory Insurance Assn., told of the use of the "welding permit" system as a means of eliminating fires, or reducing the size of fires, as well as educating personnel using cutting and welding equipment.

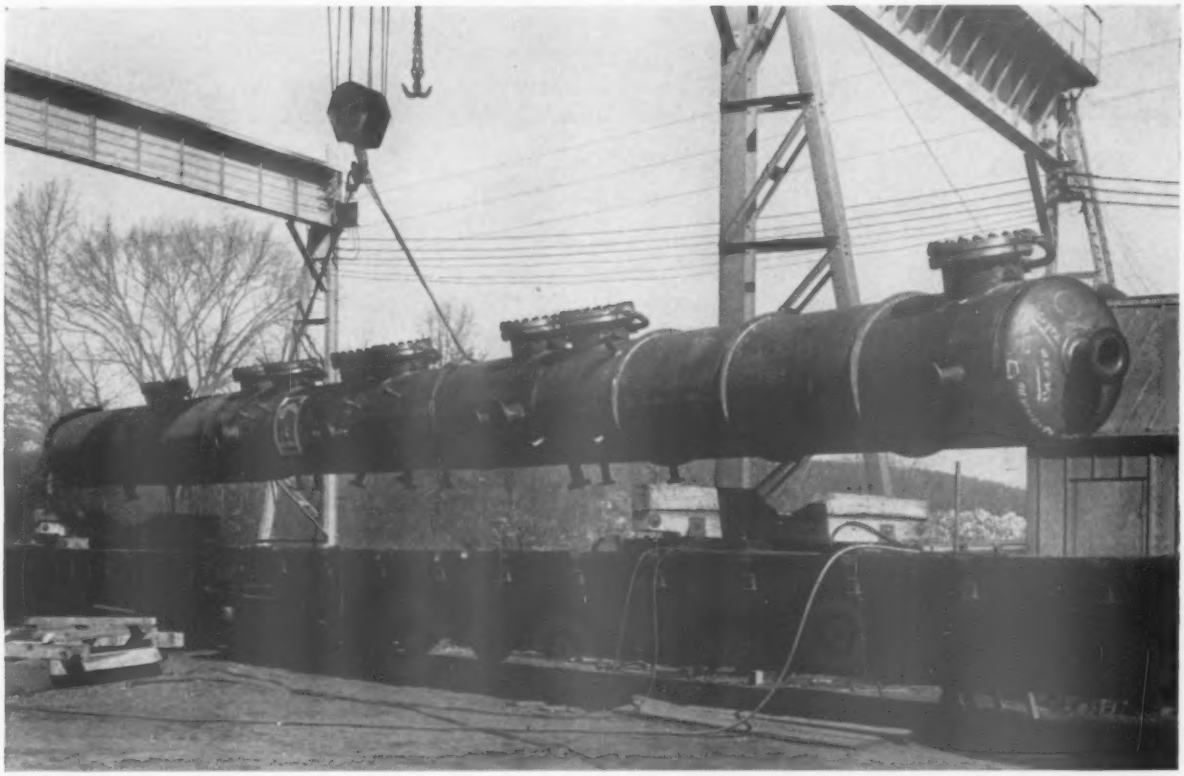
Causes of distortion in welding and preventative means were outlined by J. R. Stitt, research and welding engineer, R. C. Mahon Co. He showed samples of beams that had been badly bent during fabrication or service and subsequently straightened by the application of heat in a proper pattern.

WITH THE THIRD MIDWEST WELDING CONFERENCE

Pictured at a January 30 luncheon at the third annual Midwest Welding Conference in Chicago were (*left to right*): Clarence E. Watson, Armour Research Foundation; Gustav A. Rehm, chairman, Sangamon Valley Section; Conference Chairman Harry Schwartzbart, Armour Research Foundation; Glen O. Fruit, chairman, Iowa-Illinois Section; Haldon A. Leedy, director, Armour Research Foundation; Francis J. Harencki, chairman, Milwaukee Section; and O. T. Barnett, Armour Research Foundation

Speakers at the opening session were, seated (*left to right*): J. E. Dato, Linde Air Products Co.; George Linnert, Armco Steel Corp., and R. C. Singleton, Nelson Stud Welding. At rear are Mr. Schwartzbart (*left*) and Mr. Fruit

Welding applications in the nuclear field were discussed at the January 30th afternoon session. Mr. Harenkci (*left*), was chairman. Speakers were: Norman Block, P. Patriarca, and F. V. Daly



Welded with dependable

Downingtown weldors found Arcaloy Type 310 AC-DC the ideal electrode for the many welds in this vessel. Shown above they are working on the final assembly welds between the 410 clad section and the mild steel section.

*Division of:
PRESSED STEEL TANK COMPANY,
Milwaukee 14, Wisconsin

ARCALOY

STAINLESS STEEL ELECTRODES

Downingtown Iron Works, Inc.* used Arcaloy stainless steel electrodes in the fabrication of this 80′ refinery stripper tower. They chose Arcaloy Type 310 AC-DC electrodes for welding the 48″ diameter clad section and for joining it to the 42″ diameter steel section. Fabricated under API-ASME code, this vessel had to have welds of x-ray quality. The Downingtown staff knew that dependable Arcaloy stainless steel electrodes would produce these sound welds.

This stripper tower is typical of the fine products of Downingtown Iron, products that reflect the efficient planning, skilled workmanship and thorough service of this outstanding builder of equipment. Arcaloy stainless steel electrodes were *their* choice—and should be yours, too—for producing high quality weldments.

For complete information on dependable Arcaloy stainless steel electrodes, see your Alloy Rods distributor or write:

General Offices and Plant
Lincoln Highway West • YORK 3, PENNSYLVANIA
Pacific Coast Sales Office and Plant
750 Lairport Street • EL SEGUNDO, CALIFORNIA

Alloy Rods Co.

no finer electrodes made . . . anywhere

Section News and Events

as reported to Catherine O'Leary

American Welding Society Charters Two New Sections

With the chartering of two new sections, one in New Hampshire and the other in North Carolina, the AMERICAN WELDING SOCIETY now has 80 active sections throughout the United States.

The Carolina Section, with headquarters in Raleigh, N. C., was formed to serve the needs of AWS members in North Carolina. It is the 79th section of the SOCIETY. Charter officers of the new section are: Chairman, Prof. R. L. Cope, North Carolina State College, 1st vice-chairman, W. C. Rankin, Carolina Welding Supplies, Inc.; 2nd vice-chairman, O. K. Barnes, Westinghouse Electric Corp.; secretary, Walter T. Hoyle, Carolina Welding Supplies, Inc., and treasurer, B. S. Hayes, Eastern Distributors, Inc.

A charter as the 80th AWS section has been granted to the 50 members of the New Hampshire Section with headquarters at Manchester, N. H. It is contemplated that the activities of the section will be of service to the entire state and possibly adjourning areas. Founding officers of the new section are: Chairman, J. C. Swann, New Hampshire Welding Supply Co.; 1st vice-chairman, Robert Worrell, Lyons Iron Works, Inc.; 2nd vice-chairman, Robert Tuttle, Public Service Company of New Hampshire; secretary, Alfred B. Pennimann, New Hampshire Welding Supply Co., and treasurer, Albert Gilbert, Gilbert Welding Co. The New Hampshire Section was founded largely through the efforts of Sidney Low, Champman Valve Manufacturing Co., Indian Orchard, Mass. Mr. Low is district director of the AWS New England area.

COST STANDARDS

Albuquerque, N. Mex.—An interesting session on standards and costs, and their relation to production, took place on February 14th when the *Albuquerque* Section met for their regular monthly meeting in the Industrial Arts Building of the University of New Mexico. Speaker was Lee S. Hower, ACF Industries, Inc., Albuquerque. Mr. Hower spoke with an assurance which indicated considerable experience and knowledge of the subject.

WELDED PIPING

South Boston, Mass.—The *Boston* Section's February meeting was held at the Westinghouse Warehouse and Auditorium on the 11th. After enjoying pre-dinner refreshments and a delicious roast-beef dinner, a most receptive audience gathered in the auditorium to hear R. T. Pursell AWS, of the Stone and Webster Engineering Corp.

Mr. Pursell's talk dealt with the welding of high-pressure, high-temperature steam piping and piping for primary cooling in nuclear power plants using the various chrome-moly and stainless-steel alloys. With the aid of many excellent slides, the speaker reviewed the many problems encountered in this type of work and explained several new techniques used in coping with these problems. A different approach to edge or end preparation, employing a flare down that results in a self-contained consumable backing proved most interesting and was discussed at some length. Another item discussed was the use of portable clamp-type induction heaters adjustable to several pipe diameters for post-weld stress relief. He indicated that although the initial cost of such equipment is high, its simplicity and ruggedness is conducive to long life. A general discussion of the use of inert-gas tungsten-arc welding for root passes, the internal inspection of the same, purging techniques and the economics involved in all phases of this type of operation completed the presentation.

Mr. Pursell's down-to-earth approach to a subject of this nature made for a most enlightening and interesting meeting that drew much favorable comment from those present.

DISTORTION CONTROL

Bridgeport, Conn.—The *Bridgeport* Section met on February 21st for dinner at the Fairway Restaurant and meeting at the General Electric Co. plant.

Technical speaker of the evening was Prof. Herbert A. Sawyer, associate professor of civil engineering at the University of Connecticut. Prof. Sawyer was formerly employed by the Chicago Bridge & Iron Co. where he was in charge of the construction of floating dry docks for the Navy.

The speaker gave an excellent account of the problems faced in the construction of dry docks for the Navy and also the many problems which are encountered due to distortion of the massive plates being fabricated.

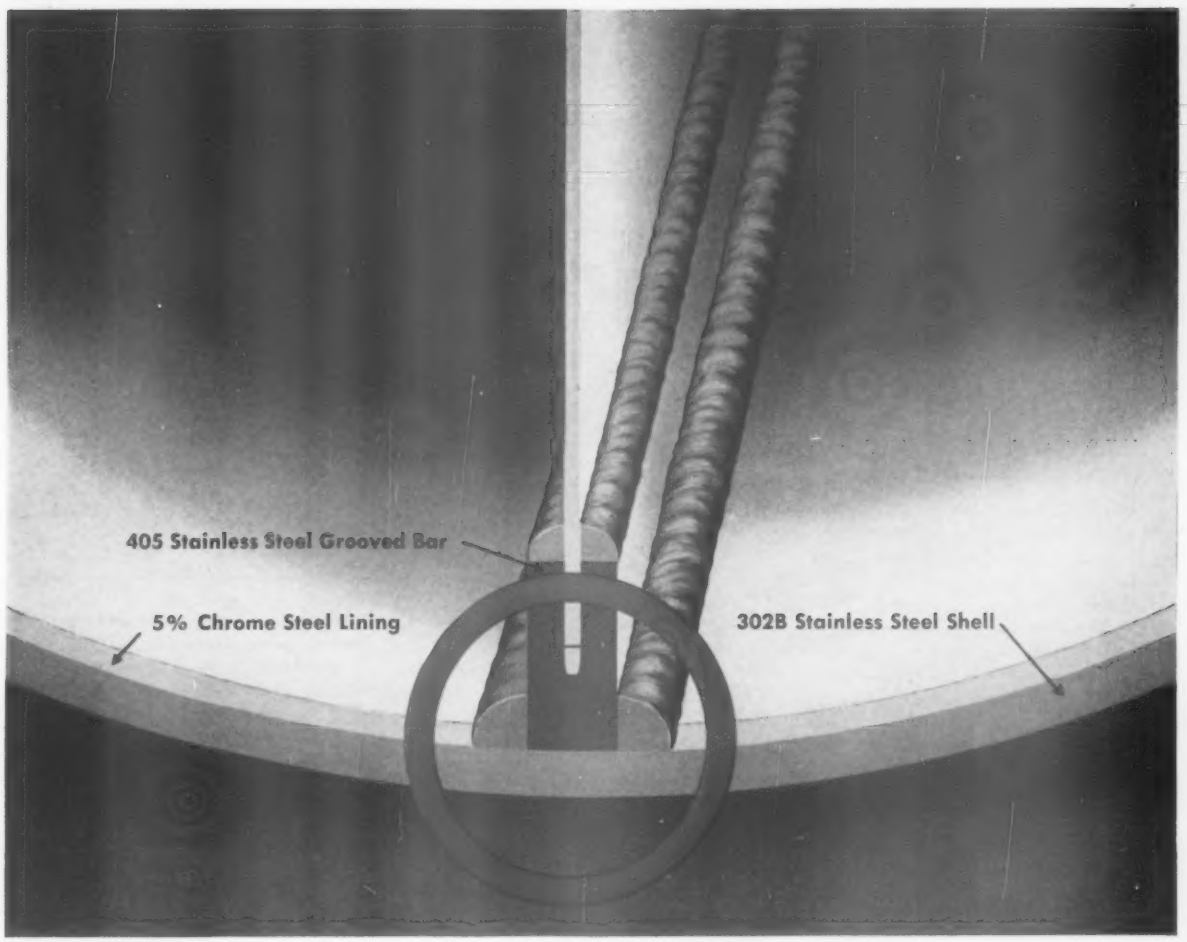
INERT-GAS WELDING

Raleigh, N. C.—The newly formed *Carolina* Section held its regular monthly meeting on February 25th.

Following dinner and business meeting, the technical meeting was turned over to W. O. Couch AWS, technical sales supervisor for Air Reduction Sales Co. Mr. Couch gave a very instructive talk accompanied by a movie on inert-gas metal-arc welding as applied to aluminum, bronze, copper, zirconium, titanium and stainless steel.

DISCUSSES ELECTRODES

R. K. Lee discussing low-hydrogen electrodes before Chicago Section on February 15



Inco-Rod "A" welds 3 steels at one joint!

Salvages vessel with cracked welds

The vessel you see above was originally designed for 302B Stainless Steel Shell . . . 5% chrome steel lining . . . 5% chrome grooved bars to hold a baffle plate in position.

Trouble developed when these grooved bars were welded into the vessel. Despite preheating, a Zyglo test revealed cracks all along the joint. Weld repair was hopeless.

Then someone suggested an ingenious solution: *Substitute 405 Stainless Steel grooved bars. That way you eliminate the need for preheat. Then use Inco-Rod "A"* electrode to weld the 405 to both 302B shell and 5% chrome lining.*

It worked like a dream! Inco-Rod "A" electrode joined the *three steels* with strong, sound, crack-free welds!

Do you need to weld dissimilar alloys? Ferritic or austenitic stainless steels, low alloy or mild steels, high nickel alloys, copper-nickel or other alloys? Then try Inco-Rod "A". . . the electrode with the green flux coating . . . because it gives strong, ductile, corrosion-resisting welds . . . of X-ray quality.

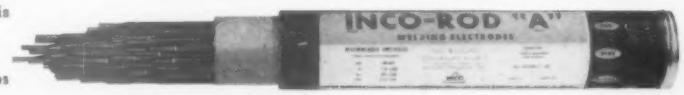
You'll like the way Inco-Rod "A" electrode *handles*, too. It's operable in all positions. Gives spray-type arc . . . easy slag removal.

Write Inco and ask about the dissimilar alloys *you* want to weld. Our welding specialists constantly bring new data about Inco-Rod "A" electrode in from the field . . . and this information may provide a ready answer to your welding problem.

*Trademark of The International Nickel Company, Inc.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York 5, N. Y.

INCO-ROD "A" electrode is supplied in 14-inch lengths in four diameters, 3/32-, 1/8-, 5/32-, and 3/16-inch (the 3/32-inch is center grip) . . . packed in 5-lb. containers.



INCO **Welding Products** • electrodes, wires, fluxes

LOW-HYDROGEN ELECTRODES

Chicago, Ill.—Approximately 40 members and guests of the *Chicago* Section met for dinner at Milner's Restaurant on February 15th. About 100 were present at the meeting which followed in the auditorium of the People's Gas Light & Coke Co.

Principal speaker was R. K. Lee AWS, vice-president in charge of research, Alloy Rods Co., York, Pa. Mr. Lee discussed low-hydrogen electrodes and his talk was followed by a lively question and answer session. Also on the evening's program was a color film on British Columbia.

INERT-GAS WELDING

Denver, Colo.—Forty-two members and guests of the *Colorado* Section were present at a dinner meeting held on January 8th in the Festival Room of the Oxford Hotel.

The main speaker of the evening, J. E. Dato AWS, Linde Air Products Co., New York, who was to have addressed the Section members on the subject of "Inert-Gas Welding", could not be present. Mr. Dato's plane was stranded in Colorado Springs.

The coffee speaker, Section member Horace Jackson of the Thompson Pipe and Steel Co., extended his talk and, with some extra color slides and humorous stories, he plugged the gap very well. A good time was had by all.

NONTECHNICAL MEETING

Denver, Colo.—Thirty-four members of the *Colorado* Section attended a dinner meeting on February 12th in the Festival Room of the Oxford Hotel.

A rare treat was in store for the audience in a talk given by Sergeant J. S. Moomaw of the Identification Bureau of the Denver Police Department on the subject of scientific crime detection. He referred to a number of actual crimes to illustrate how painstaking attention to minute details resulted in solving the crime and obtaining convictions. One of the crimes was that of the plane bombing which cost 44 lives.

Unavoidably, the main speaker was unable to get to the meeting. In his place, sound pictures of the 1956 World Series were shown.

PRESSURE VESSEL CODES

Dallas, Tex.—The February meeting of the *Dallas* Section was held on February 7th at the Delta Restaurant with 66 attending the dinner and 70 present for the technical session.

C. R. Soderberg, Jr., assistant manager, Design Engineering Department, M. W. Kellogg Co., New York, gave a highly technical talk on "Considerations Affecting Future Pressure Vessel Codes." The text of this talk was published in the December, 1956 issue of THE WELDING JOURNAL.

PLANT TOUR

Moraine City, Ohio—One hundred and fifty members and guests of the *Dayton* Section participated in a very fine tour of the Moraine City, Ohio Plant of Frigidaire.

The highlights of the two-hour tour consisted of the following: welder operation on condensers; seam welding of inner liners; spot welding of cabinets; silver soldering operations on small parts; and other spot welding operations.

LADIES NIGHT

Detroit, Mich.—Saturday night, May 18th is the date for this years' *Detroit* Section Ladies Night Party. This year, as during the past six years it will be held at the Latin Quarter.

SECTION MEETING CALENDAR

APRIL 23

OLEAN-BRADFORD Section. 7:00 P.M. Hotel Emery, Bradford, Pa. "Special Resistance Welding Applications," by J. H. Cooper, Taylor-Winfield Corp.

MAY 2

NORTHERN NEW YORK Section. Annual Meeting.

MAY 3

PITTSBURGH Section. Twentieth Annual Tri-State Ladies Night and Dinner. Georgian Room, Webster Hall Hotel, Pittsburgh, Pa.

MAY 6

LEHIGH VALLEY Section. Dinner 6:30 P.M. Meeting 8:00 P.M. Walp's Restaurant, Allentown, Pa. "Weldability."

MAY 9

PUGET SOUND Section. Technical meeting with "Induction Welding and Practical Use of Resistance Welding."

MAY 10

ST. LOUIS Section. "Specific Resistance Welding Applications," W. J. Farrell, Sciaky Bros., Inc.

MAY 14

DAYTON Section. Dayton Engineers Club, Dayton, Ohio. Welding Quiz Program.

MAY 15

SUSQUEHANNA VALLEY Section. Berwick, Pa. Dinner 6:45 P.M. Technical session 8:15 P.M. "Basic Problems in Welding Metallurgy," Austin Hiller, General Electric Co.

MAY 16

KANSAS CITY Section. Dinner meeting. Golden Ox (Livestock Exchange Bldg.), Kansas City, Mo. "Quality vs. Cost of Welding."

MICHIANA Section. South Bend, Ind. Society and business meeting.

SHREVEPORT Section. Colonial Room, Captain Shreve Hotel, Shreveport, La. Dinner 7:00 P.M. Meeting 8:00 P.M. "Position All Three, Man, Weldment and Automatic Head," Anthony K. Pandjiris, Pandjiris Weldment Co.

MAY 17

CHICAGO Section. Dinner 6:15 P.M. Milner's Restaurant. Meeting 7:30 P.M. People's Gas Auditorium, 122 S. Michigan Ave., Chicago, Ill. "Gases Used in the Welding Industry," A. F. Chouinard, National Cylinder Gas Co.

MAY 18

DETROIT Section. Ladies Night Party. Latin Quarter. Dinner, entertainment, music, dancing and door prizes for the ladies.

MAY 21

NEW JERSEY Section. Nontechnical social meeting.

SANTA CLARA VALLEY Section. San Jose, Calif. "Nondestructive Testing in the Inspection of Welds", C. E. Betz, Magnaflux Corp.

MAY 24

INDIANA Section. Hobart Bros., Troy, Ohio. "Power Supplies for Arc Welding."

NORTHWESTERN PENNSYLVANIA Section. Erie, Pa. Annual business meeting.

MAY 25

MARYLAND Section. Installation of Officers, dinner and dance.

PHILADELPHIA Section. Annual dinner-dance at Germantown Cricket Club.

MAY 27

MILWAUKEE Section. May Party.

SAN FRANCISCO Section. Plant tour. Kaiser Fabricating Plant, Napa, Calif.

Editor's Note: Notices for July 1957 meetings must reach Journal office prior to May 1, so that they may be published in June Calendar. Give full information concerning time, place, topic and speaker for each meeting.

FASTER . . . EASIER HARD SURFACING

Semi-Automatically With

Wear O Matic

PRECISION DRAWN HARD SURFACING WIRES

Now you can shorten "down-time" and turn out more resurfaced or rebuilt parts per shift with semi-automatic equipment and Wear-O-Matic precision drawn hard surfacing wires. With deposition rates up to 15 pounds per hour you can easily save up to 50% of the cost of manual hard surfacing operations and yet retain the flexibility of manual welding. In addition, with semi-automatic application there is no stub or coating loss.

***See semi-automatic demonstrations of Wear-O-Matic wire.* Visit Booth 101 at the AWS Welding Exposition, Convention Hall, Philadelphia.**

Here's why Wear-O-Matic is the RIGHT WIRE for your semi-automatic applications.

More uniform wear resistance Wear-O-Matic wires are compacted to a density almost equal to solid wire resulting in a more uniform hardness and wear resistance throughout the weld deposit.

Continuous smooth feeding The true diameter and dense structure of Wear-O-Matic wire permits smooth feeding without special feed rolls or contact tubes. Wear-O-Matic wires will not crush under standard feed roll pressure.

Find out now how Wear-O-Matic precision drawn wires can improve your hard surfacing operation. Write for free literature and application manual. Drawalloy Corporation, Lincoln Highway West at Alloy Street, York 13, Pennsylvania.

Drawalloy

CORPORATION

YORK, PENNSYLVANIA

THE WIRE MILL FOR THE WELDING INDUSTRY — STAINLESS STEEL · HARD SURFACING · TOOL STEEL

STAG PARTY HELD BY DETROIT SECTION

Members and guests enjoying "fresh ice water" at the December 14 stag party sponsored by the Detroit Section at the American Legion Hall in Detroit

Leonard Nichols and Roy Clark are adding "lemon juice to the lemonade"

The gala evening will consist of a full course dinner, entertainment, dancing and lots of door prizes for the lucky ladies.

ALUMINUM WELDING

Detroit, Mich.—The January dinner meeting of the *Detroit* Section was held at the Engineering Society of Detroit on Friday evening, January 11th.

There were 38 dinner guests present to hear Karl Klapka of the Wheel Trueing Tool Co. discuss and show a sound film on diamond mines in Southwest Africa.

The dinner guests then moved to the auditorium where a total of 75 members and guests heard from H. McClymont, Welding Engineer, Sales Development Division, and M. J. Waite AWS, Welding Dept., both associated with the Aluminum Laboratories Limited, Kingston, Ontario.

Both speakers gave a very fine presentation on modern trends in aluminum welding.

RESISTANCE WELDING TRANSFORMERS

Detroit, Mich.—A special technical meeting of the *Detroit* Section covering resistance welding was held at the Engineering Society of Detroit on January 25th. The meeting was attended by approximately 75 members and guests interested in welding transformers.

An extremely well qualified speaker on the subject was James F. Deffenbaugh AWS, chief electrical engineer for the Federal Machine and Welder Co., Warren, Ohio. Mr. Deffenbaugh held the audience's keen attention all during his talk.

MAGNETIC FORCE WELDING

Detroit, Mich.—The regular monthly dinner and technical meeting of the *Detroit* Section was held at the Engineering Society of Detroit on Friday evening, February 8th.

Dinner was served to 78 members and guests who heard Robert C. Williams, Nuclear Engineer for A.P.-D.C., the coffee speaker, on "Atomic Power at Laguna Beach". His remarks were supplemented by slides.

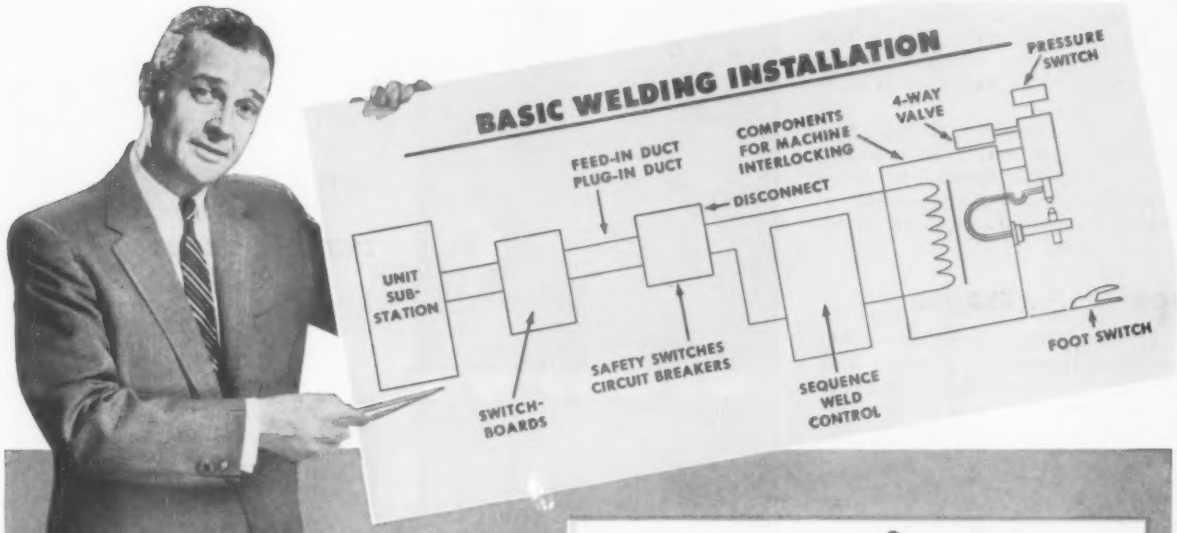
Sixty-three additional members and guests joined the dinner guests in the

DETROIT SECTION HEARS TALKS ON ALUMINUM

Karl Klapka, dinner speaker, is shown addressing members and guests present at January 11th meeting of Detroit Section

Bill Smith, Detroit Section chairman (center) is flanked by the technical speakers, M. J. Waite (left) and H. McClymont

Chairman Smith exchanging pleasantries with AWS President John J. Chyle



Here's the Easy Way

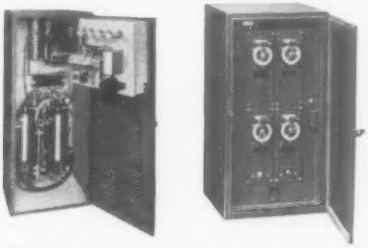
TO A BETTER WELDING INSTALLATION

• Whether you start from scratch or expand an existing operation, your Square D Field Engineer has two important things to offer to make your job easier.

First, he has the background which enables him to offer sound counsel at the planning stage. Second, he is backed by a complete line of performance-proven electrical equipment with which to put practical planning into action.

Field Engineers are available through Square D branch offices in all principal United States cities—and in Canada, Mexico and England. Backing up these engineers are the design and manufacturing facilities of 14 strategically located Square D factories and the localized services of a nation-wide network of authorized electrical distributors.

SQUARE D DOES THE *Complete* JOB!



ELECTRONIC and MAGNETIC WELDER CONTROL

SUBSTATIONS

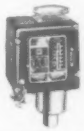
SWITCHBOARDS

FEED-IN DUCT

PLUG-IN DUCT

SAFETY SWITCHES

LIMIT SWITCHES

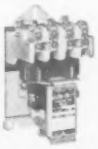


PRESSURE SWITCHES

4-WAY VALVES

PUSHBUTTONS

SELECTOR SWITCHES



CONTROL RELAYS

FOOT SWITCHES

PILOT LIGHTS

NOW...EC&M PRODUCTS ARE A PART OF THE SQUARE D LINE

SQUARE D COMPANY

auditorium and were treated to a far reaching talk on the "Theory and Development of Magnetic Force Welding." Slides were used to illustrate the talk.

After the general meeting, two movies were shown. The first was "Use of EB Ring Inserts" by Arcos Corp. The second movie, courtesy of Trans-Canada Airlines, was titled "No Barriers."

JOB SHOP WELDING

Appleton, Wis.—Lew Gilbert AWS, publishing director of *Industry and Welding*, was the guest speaker at the February 8th meeting of the *Fox Valley* Section. Mr. Gilbert's subject, "Job Shop Welding—How to Make It Pay," covered all phases, with special emphasis on methods of promoting growth and earnings.

MAINTENANCE WELDING

Appleton, Wis.—The January 18th meeting of the *Fox Valley* Section was addressed by Ted Jefferson AWS, editor of the *Welding Engineer*. Mr. Jefferson's subject was "Maintenance Welding—A National Need."

Mr. Jefferson covered a large number of applications where maintenance welding improved or salvaged parts at a lower cost and more expeditiously than replacements could be processed.

He particularly accented the hard-surfacing processes and earth-moving equipment, having had specific knowledge of this field since the time he was in charge of maintenance at the Fort Peck Dam Project.

CARBON-DIOXIDE WELDING

Indianapolis, Ind.—A highlight of the *Indiana* Section's program was the January 25th meeting at which John J. Chyle, AWS national president, was guest spaker.

Due to Mr. Chyle's presence and the interest in the topic of his talk, this was one of the Indiana Section's best attended meetings. It was preceded by a fine dinner at the Athenaeum Tourners Club in Indianapolis.

Adding spice to the program was the coffee speaker, C. A. Heffernon AWS, of Linde Air Products, who spoke on "Synthetic Gems." He related some of the historical facts and fancies of precious gems and related how many of the precious stones were now being manufactured synthetically by modern scientific methods. A large collection of these gems were exhibited and to Mr. Heffernon's relief, no cases of sticky fingers developed.

The subject of Mr. Chyle's talk was "The Carbon-Dioxide-Shielded Metal-Arc Welding Process." The early development of the process was described and traced to the present stage at which it is being used successfully on many applications. Not only is the process more economical, but it was demonstrated that in the joining of steels, welds of excellent strength and quality may be produced. Comparisons were drawn both in economics and quality with existing processes such as helium-shielded, argon-shielded, submerged-arc, and manual electrodes as related to welding of steels. Mr. Chyle indicated that, with continued application, the use of carbon-dioxide shielding would have considerable impact on the welding industry.

The talk was clearly illustrated by tables, graphs and application pictures.

DEFFENBAUGH ADDRESSES DETROIT SECTION

Pictured above are scenes taken at the January 25th meeting of the Detroit Section. James F. Deffenbaugh, shown at center in upper left-hand photo, spoke on "Resistance Welding Transformers"

INERT-GAS WELDING

Kansas City, Mo.—On February 14th, the *Kansas City* Section heard a very fine discussion with some exceptionally fine film on stringer-bead welding of low-alloy and carbon steel pipe by the inert-gas tungsten-arc welding process. It was given by Delmar Burrows AWS, of the Fluor Products Co. of Paola, Kans.

A cocktail hour and dinner preceded the meeting which took place at the Golden Ox Restaurant. It was attended by 72 members.

LADIES NIGHT

Allentown, Pa.—The *Lehigh Valley* Section held its annual ladies night on February 4th in the Green Room of the Americus Hotel in Allentown. Members and guests were welcomed by Roger Fluck, Section chairman.

F. J. Trembley of Lehigh University, Biology Department, was the coffee speaker and presented a biologist's views on the "Evolution of Man," the history of races of man and their relations to human species.

Group, square and modern dancing and music were conducted by Mr. & Mrs. J. L. Smith. J. L. Walmsley was toastmaster.

T-1 STEELS

Los Angeles, Calif.—Approximately 168 members and guests of the *Los Angeles* Section were present at the February 7th meeting to enjoy cocktails, dinner and an excellent paper presented by Leon C. Bibber AWS, chief research and welding engineer for the U. S. Steel Co., whose work is

Introducing Handy
ALUMIBRAZE
A NEW METHOD FOR JOINING ALUMINUM
HANDY ALUMIBRAZE is a powdered aluminum-silicon alloy and flux mixture for use in salt bath brazing. It can be used to join complex aluminum assemblies and has been tested and plant-proved for two years.

These Alloys Are Being Brazed With ALUMIBRAZE

Old Designation	New Designation
2S	2002
3S	3002
52S	5052
54S	5154
61S	6061
62S	6062
63S	6063
66S	6066

A612 Casting
Pioneer 40E Casting
X2219 Casting

HANDY ALUMIBRAZE is manufactured by Handy & Harman under license from The Glenn L. Martin Company. Patent applied for.

ADVANTAGES: Cost savings are immediate through the reduction of complex jigs and fixtures. Placement of the alloy is rapid, simple and sure. Alloy is preplaced in exact amount required, precisely where needed. It stays put during the brazing cycle. Even heating minimizes the possibility of warpage. And the soundness of HANDY ALUMIBRAZED joints, their strength and their corrosion resistance are equal to or better than joints made with conventional forms of filler metal.

HOW IT WORKS: Mixed with water to form a slurry, HANDY ALUMIBRAZE is applied adjacent to joints as required to fill the joints and make fillets. Assembly is then baked at 1000°F to remove moisture. This leaves the brazing alloy powder firmly cemented to the aluminum surface, the flux serving as the cement. Assembly is then dipped in molten brazing salt. The flux cement itself has a higher melting point than either the brazing alloy or the brazing salt, but it is soluble in the molten salt bath. Thus, the brazing alloy is held in place even while melting until the cement has been dissolved by the molten salt. As the flux cement is dissolved away from the molten filler metal, the alloy runs into the joint capillary spaces and also forms a generous, smooth fillet. Send for Bulletin 23. It gives full details on this modern, cost-cutting development.

WE'RE GOING TO SHOW YOU

At the Welding Show in Philadelphia, April 9, 10, 11 at the Handy & Harman Booth—#534—we'll be demonstrating salt bath brazing with ALUMIBRAZE.

Your NO. 1 Source of Supply and Authority on Silver Brazing Alloys

HANDY & HARMAN — FOUNDED 1867 — QUALITY · SERVICE

HANDY & HARMAN

OFFICES and PLANTS
BRIDGEPORT, CONN.
PROVIDENCE, R. I.
CHICAGO, ILL.
CLEVELAND, OHIO
DETROIT, MICH.
LOS ANGELES, CALIF.
TORONTO, CANADA
MONTREAL, CANADA

General Offices: 82 Fulton St., New York 38, N. Y.
DISTRIBUTORS IN PRINCIPAL CITIES

AIRCRAFT AND ROCKETRY PANEL ADDRESSED ON SPOT-WELDING CONTROLS

Mario Ochieano, chairman, Aircraft and Rocketry Panel, Los Angeles Section, shown with guest speakers, T. H. Briggs and Herbert Van Sciver at the February 7th meeting in Los Angeles

Leo West, vice-chairman of Panel presents Mr. Briggs and Mr. Van Sciver with pen sets in appreciation of a job well done

largely confined to the weldability of the various steels manufactured by his company.

Mr. Bibber's subject for the evening was "T-1 Steel Solves the Welding Problem." The new alloy, T-1 steel, being very strong and tough is capable of taking vicious abuse and yet is not difficult to weld. All of the impending values of this material and uses accumulated through research were graphically described by Mr. Bibber with the use of slides; also a motion picture in color covering the various tests conducted in sub-zero temperatures on vessels made of T-1 was shown. The program as a whole held the interest of all those present and, at the conclusion of Mr. Bibber's talk he was presented with a desk pen in appreciation of a well presented paper.

A short business session took place before the technical session. The members were sorry to hear of the illness of a three-year-old child, the daughter of one of the most active members in the Section, Jimmy O'Neil. The child has leukemia and is confined in the Children's Hospital in Los Angeles. As a spontaneous gesture of fellowship and desire to do something to help, Jim's many friends came up with a special benefit fund.

Alan Flanigan AWS, professor of engineering at the University of California presented the $150.00 scholarship award for the Spring semester to the winner, Dale F. Washburn, who attends the University of California, Los Angeles. In concluding the presentation, Dr. Flanigan advised that applications were now being accepted for candidates for the Fall semester.

RESISTANCE WELDING CONTROLS

Huntington Park, Calif.—The February meeting of the *Aircraft and Rocketry Panel* of the *Los Angeles* Section featured two outstanding speakers sponsored by The Budd Co. of Philadelphia.

The meeting was held on February 7th at the Elks Lodge in Huntington Park with 88 members and guests in attendance. The speakers were: Herbert Van Sciver AWS, staff engineer for the Budd Co.'s Nuclear Energy Engineering Division and T. H. Briggs, founder of Briggs Associates, Inc. They presented a paper entitled "Automatic Controls for Resistance Spot Welding."

The speakers described a recently-developed resistance spot-welding control system which incorporates the speed and reliability of modern radar circuits, and functions to produce welds of predetermined strength. This control system employs newly designed means of timing and heat control which are automatically adjusted during the heating period by means of a feed-back servo system. The paper was presented in two parts; Mr. Van Sciver presented the first part on the early development of the Monitor, its operation, and so forth; Mr. Briggs concluded the paper by describing the present circuit and its operation. This was followed by a discussion period at which time many questions on the subject were asked. Upon conclusion, both Mr. Van Sciver and Mr. Briggs were presented with pen sets by Leo West, vice-chairman of the

BIBBER SPEAKS ON T-1 STEELS IN LOS ANGELES

Leon C. Bibber presents paper on T-1 steel before membership of Los Angeles Section on February 7th

G. P. Murphy, chairman of Membership Committee of Section, talks on progress made in membership gains

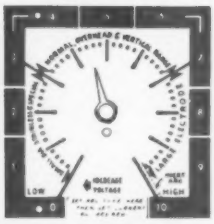
Section Chairman C. B. Smith, right, presents to Oscar Glass the moneys received from members and guests for a special benefit fund

Left to right, Leo West, Alan Flanigan, Mario Ochieano and Walt Tenner appear in a jovial mood while discussing future events.

...for those tough "HARD to WELD" jobs

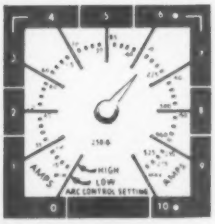
VICKERS Controlarc* DC Welder

Right at your fingertips—exact control—compact, light weight for truly versatile performance



SELECTION OF ARC TYPE

for different welding jobs, and adjustment necessary to suit your individuality and the welding job.



DUAL CONTINUOUS CONTROL

in a rectifier welder. Can vary the current from minimum to maximum, and vary the type of arc, with continuous stepless self-indicating dials.

*TRADEMARK

Gives You REMOTE CONTROL of CURRENT and TYPE of ARC

Even in those tight, cramped places, where there's hardly room to turn around, this handy little remote control box goes right with you. No matter what your welding position, you can "dial" the exact arc you need, without running back to the welder to change range switches and taps. Only the Vickers CONTROLARC gives you this individual control of current and type of arc in convenient remote control operation.

AND ONLY THE CONTROLARC GIVES YOU THESE EXCLUSIVE OPTIONAL FEATURES

Constant Potential (CP) Adaptor • Slope Controller

WRITE TODAY

for more information on this versatile welder.

DESIGN ENGINEERS:

There are openings in our expanding program. Write for details.

VICKERS ELECTRIC DIVISION

VICKERS INCORPORATED a unit of Sperry Rand Corporation

1853 LOCUST STREET • SAINT LOUIS 3, MISSOURI

Aircraft and Rocketry Panel, in appreciation of a well-presented program.

JOINT DESIGN

Madison, Wis.—Eighty-two members and guests of the *Madison* Section representing manufacturing and steel fabricating from as far south as Rockford and Chicago to Madison and Milwaukee, turned out for the February meeting held at the Eagles Club on February 14th.

This large attendance was awarded with a very interesting talk on joint design for welding as given by A. N. Kugler AWS, of the Air Reduction Sales Co. in New York. Of special interest were the changes being made in the design of joints for high-pressure pipe weldments.

WELDING METALLURGY

Baltimore, Md.—The February meeting of the *Maryland* Section was destined to be a real success from the moment the principal speaker accepted the program chairman's invitation. Gerald E. Claussen, of the Metals Research Laboratory, Linde Air Products Co., Newark, N. J., returned to Baltimore after an absence of about five years to address his old friends and fellow AWS members on "Metallurgy of Steels as Applied to Welding." His appearance on the program brought out the Marylanders "en masse," and even coaxed a car full from the hills of Hagerstown, Md. Dr. Claussen, in his usual clear-cut style, told the group that anyone responsible for making of sound weld joints could not afford to ignore the basic help gained from knowing the fundamentals of welding metallurgy. He explained the mechanism of solidification in weld metal and pointed out the factors that control shrinkage, cracking and porosity. He described the reactions which occur between carbon, oxygen, silicon, and manganese in steelmaking and illustrated the circumstances under which the selfsame reactions take place in welding and their effect upon the weld deposit. In the discussion period that followed, Dr. Claussen showed how these fundamental concepts explained a number of practical welding problems.

A short coffee talk was made before the technical meeting by Dr. Dietrich W. Smith, Ph.D, who spoke on "Frontiers in Medical Research" and showed a 16 mm visual film on medical research in Baltimore.

A. O. SMITH PLANT VISITED BY MILWAUKEE SECTION

A partial view of the almost 300 Milwaukee members of the American Welding Society in a get-together preceding an evening plant tour of the A. O. Smith Corp., Milwaukee plant, on January 28th

Carbon-dioxide semiautomatic welding of a Chevrolet frame section is viewed by A. O. Smith visitors

A. O. Smith technicians discuss in-plant welding operations in post-tour panel discussion

EDUCATIONAL COURSE

Milwaukee, Wis.—The annual "Educational Lecture and Plant Tour Course" was conducted by the *Milwaukee* Section on Jan. 7, 14, 21, 28, 1957. The attendance for the four session series, which was entitled "The Practical Welding of Various Metals," approached a total of 700 Milwaukee area members and friends. The lecture sessions of the first three meetings were held at Marquette University, while the last session, consisted of a tour of the A. O. Smith Corp. plant.

The group was honored in having National President John J. Chyle, also director of welding research, A. O. Smith Corp., give the first lecture, "The Welding of Pure Copper." Coordinated with him was F. Emery Garriot AWS, of Ampco Metal, Inc., who spoke on welding of copper alloys. Mr. Garriot also had the audience spellbound when he related his experiences and feelings in the recent explosion at his company, where two persons were killed and many were injured. Mr. Garriot plunged from his third floor office all the way into

Here's Just 3 Reasons Why So Many Welder's Have Switched

- Wrap around Glass Fibre Tip Insulation—30% *more* heat resistance than any other make!
- Brilliant Red Tips and Trigger—Bright Yellow Handle—all Glass Fibre, an outstanding Safety Feature!
- Body completely insulated—no bare spots!

HI-AMP®
ELECTRODE HOLDERS
are the most economical to buy and maintain too!

Just ask any Welding Supply Dealer anywhere for PROOF of the above statements.

LENCO, INC.
(Formerly Wagner Mfg. Co. Inc.)
JACKSON, MISSOURI

Weld with HI-AMP

the basement, by riding it out beneath the protective shielding of his metal office desk. His hobby is performing tricks of magic, but this feat with the guidance of his prayers, was practically a miracle. He was unhurt except for minor scratches.

The second session dealing with the welding of aluminum and magnesium, was a panel presentation by the following welding experts:

Paul Dickerson, Aluminum Company of America; Wm. J. Dyble, The Heil Co.; Morton J. Whitney, West Bend Aluminum; and Paul Klain, Dow Chemical Co.

A brief discussion of aluminum and magnesium specifications was given by Wm. H. Derry of Alcoa and W. J. Jacks of Dow Chemical Co.

The last lecture covered the various phases of the welding of gray, malleable and nodular irons. It was presented in a very interesting manner by Walter W. Edens, Allis-Chalmers Manufacturing Co. This lecture, as well as the previous sessions, was followed by a warm discussion from the audience. One individual even brought in an actual weldment with a cracked weld in it.

On January 28, the concluding session, the A. O. Smith Corp. extended to a group of 270 people an interesting, educational and enjoyable evening by way of a plant tour. This included visits to actual production areas where both automatic and manual carbon dioxide welding were being done. The tour included electrode manufacture, pressure-vessel fabrication, flash-welded pipe line, and the Welding Research Laboratory. The tour was concluded with a buffet lunch and a panel discussion by a number of A. O. Smith engineers, who answered questions at the close of the trip.

The Milwaukee Section of the AMERICAN WELDING SOCIETY had a highly educational course in the four sessions presented during the month of January.

AUTOMATIC HARD SURFACING

Milwaukee, Wis.—Ivan Bartter AWS, general manager of the Automatic Welding Co., Elm Grove, Wis. gave an impressive talk on "Industrial Automatic Hard Surfacing" at the February 22nd dinner meeting of the *Milwaukee* Section held at the Ambassador Hotel. Mr. Bartter is widely recognized as an authority on this subject, having had broad experience in general welding over many years. In the last five years he has established his own company, which specializes in industrial hard surfacing.

Mr. Bartter pointed out that, by the use of industrial hard surfacing as a maintenance tool, many expensive parts from mining construction in the industrial field can be salvaged and restored to conditions which are sometimes better than the original new parts, and that this can be done at tremendous savings both in time and expense.

Mr. Bartter also pointed out that while hard surfacing with the submerged-arc welding process is well-known, success of the operation depends primarily on the establishment of good procedures, and maintaining the procedures on the job so that uniformly high quality work is produced.

Mr. Bartter's thoughts on this subject were very adequately proved by the use of slides illustrating many successful applications, as well as the extremely rapid growth his company has enjoyed over the past five years.

ELECTRODES

New York, N. Y.—The second meeting of the year of the *New York* Section was held on Feb. 5, 1957. The speaker, Orville T. Barnett AWS, Supervisor of Welding Research at the Armour Research Foundation of Illinois Institute of Technology, gave a most interesting lecture.

"Why So Many Electrodes," was the speaker's topic and he proceeded to explain in detail why one electrode would not do all the jobs that had to be done, and the best method that the average welder would have, to figure out the electrode that was best suited for a particular job.

The speaker also explained many other important items in regard to welding such as the type of current that should be used, relative speed, penetration, undercutting and soundness of the welds produced. He also stressed the proper setup of the work, bridging the gap, and freedom from spatter. Finally, the speaker discussed the best type of electrodes used for welding of galvanized steels.

The entire lecture was illustrated by a series of slides which together with the lecture was very enlightening and interesting to the audience.

The meeting, as usual, was held at the Victor Restaurant, 1 E. 35 St., New York City, where an excellent dinner was served prior to the Meeting.

ULTRASONIC TESTING

Marion, Ohio—The regular monthly meeting of the *North Central Ohio* Section was held on February 1st. Twenty-six members and guests enjoyed dinner in the Plantation Room of the Hotel Harding. Bad road conditions made it impossible for more members to attend.

ACORN
BENDING BLOCKS
or
WELDING PLATENS
Semi-steel Blocks for layout, welding assembly work, etc., with machined working surfaces; also tools and accessories, including a full line of clamps, drift pins and dogging devices. Standard and special stands can be supplied. A 4-unit set-up, joined and mounted on stands, is shown above.
WRITE TODAY FOR LITERATURE
ACORN
IRON & SUPPLY CO.
Delaware Avenue at Poplar Street
Philadelphia 23, Pennsylvania

Before the meeting, the group enjoyed a movie entitled "Consumable Insert Welding," which was shown through the courtesy of the Arcos Corp. The movie showed the consumable insert ring being fused into the weld groove for the root pass without the use of filler wire. It showed how a weld can be made from one side only and still have a flat surface on the inside of the pipe weld joint.

Speaker of the evening was Ralph A. Frank, manager of Sales and Service for Sperry Products, Inc., Pittsburgh, Pa. District. Mr. Frank's topic was "Practical Ultrasonic Testing and Inspection of Material." He explained in detail the application of the equipment used and how it operated in service. Mr. Frank's talk was very well presented and he very competently answered all questions put to him.

HIGH-TEMPERATURE ALLOYS

Knoxville, Tenn.—On January 21st the *Northeast Tennessee* Section had a dinner meeting and technical session at the S & W cafeteria in Knoxville. The guest speaker was Gordon P. Parks AWS, of the Solar Aircraft Corp., Des Moines, Iowa.

NCG "Type R" automatic cutting machines—3 of them—help speed production at the WHITING CORPORATION, Harvey, Ill., one of the nation's leading producers of foundry and railway equipment, material handling equipment, rotary shears, chemical equipment, and special machinery. Two of the machines, as shown above, are mounted on one long table to provide a 40-foot cutting length. Parts being cut in this picture are for Whiting's "Trackmobile."

MERCURY MANUFACTURING CO., Chicago, uses this NCG "Type JR" stationary cutting machine for close tolerance shape cutting of parts that go into the manufacture of their well known line of "Mercury" fork-lift trucks.

"We'd be lost without our CUT-O-MATIC portable" says Ralph Long of J & L ENGINEERING CO., Chicago. "We use it for everything from beveling heavy plate (above) to cutting strips, circles, arcs and rings in light gauge up to heavy sections."

Bring on ANY flame cutting job!

Do you do large scale cutting . . . large in size or large in quantity?

Then the NCG "Type R" is the machine for you. It lets you mount up to 8 torches at once for tremendous output. It cuts shapes up to 10 feet in diameter . . . as small as 1½ inch in diameter. A beveling device can be added for making accurate bevels of all types on plate up to 2½ inches thick. Since the "Type R" is built to order, any of its eight standard forms can be varied if necessary to meet your exact needs—and varied later, too, to meet changing needs. And it will give you long dependable performance: the first "Type R"—installed more than fifteen years ago— is still in service.

Do you need fast, accurate cutting on a medium scale?

If so, it will pay you to get the facts about the NCG "JR" cutting machine. A junior version of the big "Type R," it handles any cutting job you can think of—straight line or shapes, manual or template tracing—on plate up to 3 x 4 feet.

Do you want to mechanize hand cutting operations?

Then ask for a demonstration of the CUT-O-MATIC®—an inexpensive portable cutting machine that weighs just 30 pounds, complete with torch. It cuts circles, arcs, straights, does stack cutting, pipe cutting . . . all with production-line accuracy. An exclusive "floating torch" assembly lets you cut accurate bevels even on wavy plate.

NATIONAL CYLINDER GAS COMPANY
840 NORTH MICHIGAN AVENUE, CHICAGO 11, ILLINOIS
Branches and dealers from coast to coast

© 1957, National Cylinder Gas Company.

When you work with metals . . . work with NCG®

No matter what the job . . . in cutting, welding, brazing, or metal conditioning . . . NCG has the equipment, the experience and the organization to serve you better.

VISIT OUR BOOTH 244 — WELDING SHOW
APRIL 9-11, 1957 • PHILADELPHIA, PA.

ELECTRODES AND GAS RODS ★ ARC-WELDERS ★ CUTTING MACHINES ★ HIGH PURITY GASES
CUTTING AND WELDING TORCHES ★ WELDING AND CUTTING ACCESSORIES

PARKS SPEAKS BEFORE NORTHEAST TENNESSEE SECTION

Seated at the speaker's table at the January 21st meeting of the Northeast Tennessee Section were left to right, J. M. Case; J. C. Thompson, section chairman; Gordon P. Parks, guest speaker; and E. C. Miller, Southeastern District director

Mr. Parks talked about the "New Look" in welding, presenting applications and problems involved in welding high-temperature alloys used in jet engine assemblies. Much of his talk pertained to development of specific procedures and modifications of basic equipment to provide rapid and successful welding of various bimetallic components. In many cases, it was the fixtures and the timing cycles that made the welding jobs feasible. The biggest problem that his plant has encountered has not necessarily been the development of welding techniques, but rather the obtaining of parts from the fabrication shops which, when fitted-up, would meet dimensional specifications and tolerances, thereby permitting them to be welded successfully in position.

The gathering was impressed with Mr. Parks' talk since, in many cases, those present were familiar with similar problems in manufacturing weldments.

AUTOMATIC WELDING

Bradford, Pa.—The regular monthly dinner meeting of the *Olean-Bradford* Section was held on February 19th at the Hotel Emery in Bradford.

The featured speaker of the evening was Harry Bichsel AWS, of the Westinghouse Electric Corp., Buffalo, N. Y. Mr. Bichsel spoke on automatic welding progress and savings over manual operations. His talk was illustrated with about 45 slides and a ten-minute film.

HIGH-TEMPERATURE ALLOYS

Pittsburgh, Pa.—Thirty-two members and guests of the *Pittsburgh* Section were present at dinner on February 20th at the Hotel Webster Hall and were joined by 32 additional members and guests for a meeting in the auditorium of the Mellon Institute of Industrial Research.

A before-meeting treat was the showing of an excellent sound, color film on "Consumable Insert Welding" provided by the Arcos Corp., Philadelphia.

The members and guests were treated to an excellent discourse on "High-Temperature Alloys," as given by Frank M. Richmond, manager of materials research for the Universal Cyclops Steel Corp., Bridgeville, Pa. The presentation covered research applications and new processes and was of interest to the members of the production department as well as to engineers and executives.

WELDING POWER

Portland, Ore.—The regular monthly meeting of the *Portland* Section was held on January 7th in the Heathman Hotel.

The speaker of the evening was Howard Long AWS, of General Electric Co., Seattle, Washington. The subject—"Living with Lightning." He made a good practical talk on welding and welding power. He also had some samples of steel welding with the consumable-wire process and CO_2 shield.

Emil Kilham made a complete report on the Scholarship Program. For the present they will work only with Oregon State College.

The meeting was attended by thirty-one members and guests.

NUCLEAR POWER

Seattle, Wash.—"Nuclear Power—Future of the Welding Industry" was the topic of the evening at the February meeting of the *Puget Sound* Section, held on February 14th. John Bert AWS, head of Welding Engineering Branch at the Puget Sound Naval Shipyard, Bremerton, Wash., spoke on many aspects of welding nuclear assemblies for the new power industry.

Mr. Bert's discussion was based on a great amount of factual information from authoritative sources that he has developed from following the nuclear power field growth over the past 15 years. An enlightened discussion of the various types of reactors now being built or operating followed a brief outline of how nuclear chain reactions are started.

A twelve-minute film on "Consumable Insert Welding" was shown following the talk. Fifty members and guests were in attendance for the dinner meeting.

QUIZ PROGRAM

Rochester, N. Y.—The *Rochester* Section has had a very busy February with a dinner-dance in addition to their regular monthly meeting.

The annual dinner-dance, attended by about forty couples, was held at the Hospitality House on Saturday evening, February 9th. Cocktails, dinner, dancing and entertainment provided an enjoyable time for the members and their wives, who braved the inclement weather to attend.

On February 18th, the Section held its annual intra-section "Stump the Experts" evening at the Liederkranz Club. After dinner, three teams participated in a program patterned after the popular "$64,000 Quiz" program of TV fame. In this case, the category, chosen blindly by the contestants, was made up of successively more difficult questions with the final problem valued at 64,000 points. The validity of the answers were judged by a panel composed of Bob Waldvogel, welding engineer, Stromberg Carlson; Harry Stoler, sales engineer, Welding Products; and Walter Kazoroski, Delco.

The members of the successful team from the Pfaudler Co., with a total score of 68,000 points, were Dick Avery, Burt Payne and Bob Haslip. The second place team with 66,000 points was from the Foster Wheeler Corp. and its members were Bob Lawrence, Nels Martin and Mal Kenney. The third place team was a "dark horse" group made up of experts from three companies: Walter Dick, Kodak; Frank Comisso, United Welding Service; and Howland Jacobs, American Machine & Foundry.

The moderator, Dan Masterson of

Plant, Research Laboratories and World Headquarters

BETTER ORIGINAL FASTER
Low Temperature EUTECTIC WELDING ALLOYS
STRONGER WELDS

EUTECTIC Welding News

PUBLISHED BY EUTECTIC WELDING ALLOYS CORPORATION, 40-40 172 STREET, FLUSHING 58, NEW YORK, N. Y.

"EUTECTIC" WELDING HEADLINES • TIME • MONEY • MACHINERY SAVERS

AUTHORITY ON WELDING, DR. G. M. A. BLANC TO LECTURE IN THE UNITED STATES IN APRIL

Rene D. Wasserman, President of Eutectic Welding Alloys Corporation, has announced that Dr. of Engineering G. M. A. Blanc, in charge of research activities of Castolin, European affiliate of the international "Eutectic" organization, will visit the United States in April. Dr. Blanc, who received the doctorate in electrical engineering from the Swiss Polytechnic Institute in Zurich, is head of the Brazing Committee of the International Institute of Welding, and a popular lecturer at European universities interested in welding research.

During his visit here, Dr. Blanc will lecture at Massachusetts Institute of Technology and other American and Canadian colleges and universities. He will also hold consultations with leading research and welding specialists of American industries.

Dr. Blanc will speak on the following subjects of major importance to welding and research specialists: "The Experimental Determination of Bonding Temperatures"; "Production Brazing"; and "Fundamentals and Applications of Low Heat Joining of Metals."

To all who are interested in the latest welding research developments, Dr. Blanc's talks should prove stimulating and useful. Reprints are available free on request from Eutectic's Technical Information Service. *(A-61)*

9 TON SHAFT OVERLAYED BY EUTECROD 185 IN 8 HOURS

The bearing end of this nine ton, 23-foot stoker drive shaft was badly worn by 21 years of operation. An eastern utility company thought repair would be lengthy and expensive until Eutectic's District Engineer suggested EutecRod 185, patented BronzoChrom overlay with highest resistance to frictional wear. EutecRod 185 repaired the shaft in eight hours, with great savings in materials and labor.

Overlays were applied without raising the shaft above cherry red in color: EutecRod 185 bonded without fusion of base metal at temperatures between 1000° and 1200° F. Harder and tougher than conventional bronze overlays, EutecRod 185 overlays have high ductility, low coefficient of friction, and excellent corrosion resistance, now give shaft excellent resistance to wear and impact. *(A-62)*

EUTEC-CHAMFERTRODE SPEEDS CUTTING AND CLEANING TIME

A Texas oil refinery dis-assembling worn catalysp chains before rebuilding them tried a number of conventional cutting methods without achieving clean, fast cutting. Eutectic's District Engineer recommended Eutec-ChamferTrode, high speed gouging electrode for all metals. Fast, clean cutting action of ChamferTrode resulted in faster dis-assembling, easier re-welding. ChamferTrode requires no oxygen or special equipment. Its

exothermic coating concentrates the force of the arc right at the point of application, yielding a highly efficient metal removing tool. *(A-63)*

In answering industry's requests for technical data, Eutectic's research and engineering staffs help industry save thousands of dollars each year. Your question, like those below, will be answered without obligation by Eutectic's Technical Information Service.

Q. We have found Eutec-TinWeld ideal for manufacturing several of our products. For large scale production, what method would you recommend for applying TinWeld to the parts to be welded?

A. We suggest you test these two methods to see which best suits your needs. After thinning, Eutec-TinWeld can be applied by using mechanical rollers to transfer automatically the paste from the hopper. A constant uniform supply can be produced with a series of three rollers, one transferring to the other. The second method is to use a pump ejection system. Fill a cylinder with Eutec-TinWeld and force it through an opening with a piston. By using compressed air, this method can be used to dispense the paste from an overhead hopper, as well as spraying it through an atomizer.

Q. We are a large newsprint and paper manufacturer and require a great deal of hard overlaying of chipper bed knives. What EutecTrode do you recommend for this application that will provide exceptional edge retention qualities?

A. EutecTrode 6-HSS is ideal for your needs. Its special "Frigid Arc" coating permits welding at lowest possible amperage, with minimum dilution and great freedom from porosity. It produces a hardness of RC 62.

See "Eutectec's" Booth 200
American Welding Society
Fifth Annual Welding Show
April 8-12
Philadelphia, Pa.

Eutectic Welding Alloys Corporation
40-40 172nd Street, Flushing 58, N.Y.

Gentlemen:

I would like further free information on the following:

☐ A-61 ☐ A-62 ☐ A-63
☐ Free 170 page pocket Welding Data Book.

Name_____

Business Address_____

City_____ State_____

WELDING PROCESSES DISCUSSED BY BARNETT

Orville T. Barnett (third from left at speaker's table) talked on the subject of welding processes at the January 21st meeting of the San Francisco Section. He is flanked by S. M. Whitmer, left, and Fred Stettner, Section chairman, right

Jackson Welding Supply, did an excellent job as referee and judge "extraordinaire."

WELDING PROCESSES

San Francisco, Calif.—The *San Francisco* Section held its initial meeting of 1957 at the El Jardin Restaurant on January 21st. The meeting, which was attended by 85 members and guests, including students and welding apprentices, was preceded by a social hour and dinner and was addressed by Orville T. Barnett (AWS), assistant manager of Metals Research of the Armour Research Foundation of the Illinois Institute of Technology.

In elaborating on his subject, "Which Welding Process and Why," Mr. Barnett classified welding into consumable and nonconsumable electrode processes, described the methods which fell into each class and their importance in industry. He pointed out the general applications for tungsten-arc and metal-arc welding in inert-gas shields and emphasized the boon which the consumable-electrode inert-gas-shielded arc process has been to the welding of aluminum.

He had prepared many charts displaying the adaptability of various welding processes to the "who's who" of ferrous and nonferrous alloys, pointing out that the weldability ratings were based not only upon feasibility but quality of welds and their cost.

Mr. Barnett was an entertaining as well as instructive speaker.

LOW-HYDROGEN ELECTRODES

Shreveport, La.—The *Shreveport* Section met on February 21st at the Captain Shreve Hotel.

Technical speaker was James Ruckman of the Alloy Rods Co., who discussed the subject of low-hydrogen electrodes.

Conventional low-hydrogen electrodes have been in wide use for a number of years for welding hard-to-weld steels such as: high-carbon, high-alloy and sulfur-bearing steels. These electrodes have certain disadvantages such as: the arc length is critical. If the arc is too long, porosity results; and if the arc is too short, spattering and shorting out results. Starting technique is important in eliminating porosity—welding over starting point. Uneven bead is also hard to clean when welding with conventional low-hydrogen electrodes.

In recent years, low-hydrogen electrodes with iron powder in coating have come into existence. These iron-powder electrodes have certain advantages over conventional low-hydrogen electrodes. Iron powder eliminates most shorting out, as well as starting porosity, and allows electrical energy to be used more efficiently. Iron powder allows increase in electrical energy without increasing penetration and gives a smoother weld which is easier to clean. Iron powder improves arc stability—fine metal transfer, that increases speed in all welding positions. Tests have shown that iron-powder low-hydrogen electrodes gives 11% increase in speed over conventional mild-steel electrodes.

With low-hydrogen iron-powder type electrodes weld defects that cause rework is at a minimum.

The iron-powder electrodes are easy to use resulting in less operator fatigue.

Iron-powder low-hydrogen electrodes have replaced E6010 and E6012 electrodes in fabricating in many places due to better X-ray

AT JANUARY MEETING OF SANTA CLARA VALLEY SECTION

Seated at the head table, during the dinner which preceded the meeting of the Santa Clara Valley Section on January 22nd, are V. Zacharenko, R. Skow, M. Sebastian, guest speaker O. T. Barnett, F. Masdeo, J. Richter, H. Gerin, B. Smith, R. Townsend and R. Parkman

Mr. Barnett in the process of delivering his talk on the subject of welding processes.

WELDING CLINIC HELD BY TOLEDO SECTION

A clinic on inert-arc welding was held by the Toledo Section on February 18th. At left, R. Minga discusses a completed root pass with the class. At right, L. Rash analyzes some samples made by the CO_2 process

quality, less rework, higher welding speeds, deposition rate and greater recovery.

INERT-ARC WELDING CLINIC

Toledo, Ohio—As part of the February meeting of the *Toledo* Section, an Inert-Arc Welding Clinic was held at the Toledo Edison Demonstration Room. This clinic was conducted by the Air Reduction Co. and the Linde Air Products Co., and was for the purpose of educating engineers and operators in proper technique for inert-arc welding. Classes were of three-hour duration, and the admission fee was $2.50 per person.

Ralph Minga of Linde Air conducted the inert-gas tungsten-arc welding phase of the clinic and was assisted by Oran Fisher. At this phase, two rectifier welders were set up with inert-gas tungsten-arc welding torches and 10-in. schedule 40 pipe used for welding specimens. Mr. Minga concentrated on root pass welding in pipe using the inert-gas tungsten-arc process and began his class by discussing various joints used with this process, and the advantages of each. He then took the torch and made a root pass weld in various welding positions, being careful to describe the "signposts" of a good weld in each position. The torches were turned over to the class and their individual welding technique studied and corrected. Questions on technique changes for various metals were answered, and wherever possible, demonstrated.

Luke Rash of Air Reduction Co. conducted the inert-gas metal-arc welding phase and was assisted by Merle Baughman. Mr. Rash began his phase by discussing inert-gas metal-arc welding in general and the effects of various shielding gases. He then demonstrated an automatic procedure using the carbon-dioxide process as used on a fillet weld on light-gauge production-line fabrication. This was followed by a discussion and demonstration of aluminum welding, by manual operation of an inert-gas metal-arc welding gun. The equipment was turned over to the class and improper welding technique corrected. The use of the process for welding various metals was then discussed and techniques detailed.

These classes were conducted Monday and Tuesday, February 18th and 19th, and were attended by 105 members and guests. Everyone indicated that they had picked up considerable information, and were beginning to see where these processes could play a part in their welding operations.

The regular February meeting of the Toledo Section was held on the evening of February 19th at the Maumee River Yacht Club. Following dinner, which was attended by 55 members and guests, the crowd was entertained by color slides taken at the clinic by Section treasurer, Sam Snell.

The speakers for the evening were the men who conducted the clinic, namely, Mr. Minga and Mr. Rash. They reviewed the points of importance in each process and reviewed the main items covered during the clinic. With Roy Hoeffler, Section secretary, acting as moderator, they answered a variety of questions on each process as presented by those present.

The 105 people who attended the clinic and the 107 who attended the meeting were pleased to see two progressive companies come into the area to teach quality welding, with no sales talks combined.

PLANT TOUR

Wichita, Kans.—The February meeting of the *Wichita* Section was held in the nature of a tour of the Boeing Airplane Plant on February 11th. After dinner in the plant cafeteria, the group was conducted through the following departments: sheet-metal fabrication, heat treatment, materials department, welding shop, heat treat and final assembly. One of the two highlights of the tour was the production demonstration of the new process of inert-arc cutting of aluminum plate. The other high point of the tour was in the final assembly where the group was able to see the B-52 at close range.

APPLICATION OF WELDING

Worcester, Mass.—The February 4th meeting of the *Worcester* Section was held at Nick's Grille in Worcester, Mass. There were 65 members present for dinner.

The speaker of the evening was Roger W. Clark [M2], welding engineer, General Electric Co., Schenectady, N. Y. He presented a very lucid and enlightening discussion of the Technical Activities Committee's proposal entitled "Basic Principles for the Application of Welding."

Using cards to illustrate his points, Mr. Clark proceeded to explain the thinking of the Committee on the nine general factors mentioned in the proposal: (1) Service conditions; (2) general design layout; (3) materials; (4) detail design; (5) joint welding procedures; (6) welding sequence; (7) qualification; (8) supervision and (9) inspection.

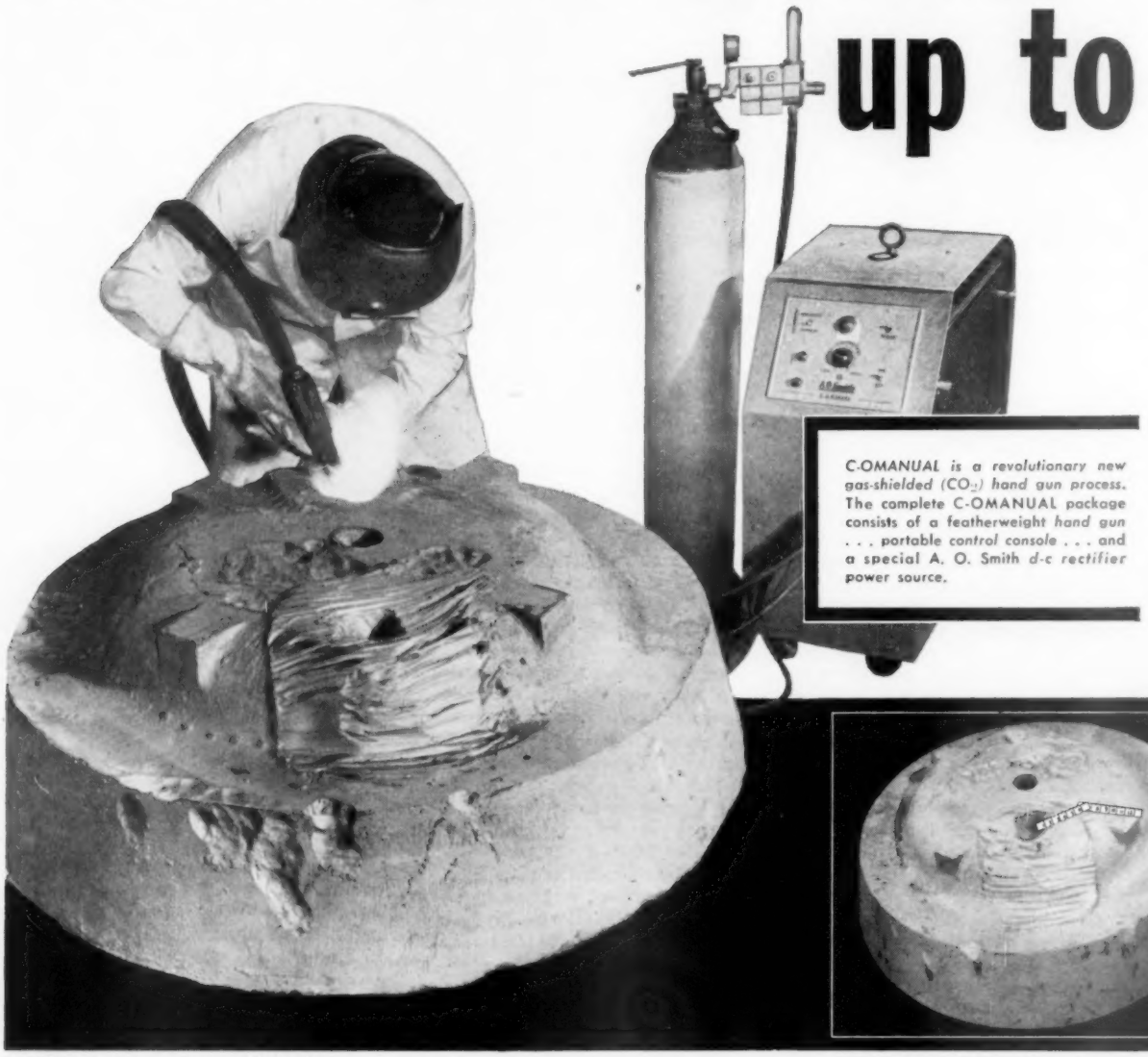
Mr. Clark stressed, in particular, that these proposals are just what the name implies. They can be amended and, quite likely, may be. Their object at the moment is to invite criticism and thereby arrive at an industry-wide cross section of opinion. They will ultimately be presented for approval and adoption.

Following the talk, Mr. Clark spent about a half hour answering questions on several phases of the Committee's activities. He handled the subject remarkably well and at the close of the meeting, the members present extended to him a vote of thanks.

JOIN NOW!

If you are interested in better welding, lower fabrication costs and increased productivity, you will gain from investment in AWS Membership. You can learn how to join by writing AMERICAN WELDING SOCIETY, 33 West 39th Street, New York 18, N. Y.

Midwestern foundry salvages castings... up to



C-OMANUAL is a revolutionary new gas-shielded (CO_2) hand gun process. The complete C-OMANUAL package consists of a featherweight hand gun . . . portable control console . . . and a special A. O. Smith d-c rectifier power source.

C-OMANUAL setup — operator with hand gun, portable remote control console and A. O. Smith 600 amp d-c rectifier not visible in illustration.

Here's a casting, imperfect to be sure, but economically salvageable thanks to low-cost, high-speed C-OMANUAL.

Typical comparison of C-OMANUAL and Hand Arc operations in a foundry

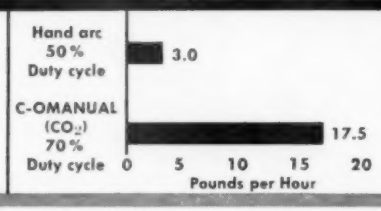
PROBLEM: Repair and build up large steel casting.

	C-OMANUAL (CO_2)	E-6013 HAND ARC
Wire Diameter	1/16"	1/4"
Amperes	450	315
*Duty Cycle %	70	50
†Efficiency %	98	65

***DUTY CYCLE** — Lower on hand arc due to necessary stops for slag removal, electrode changes, etc.

†**EFFICIENCY** — Lower on hand arc due to coating loss, stub loss, spatter, etc.

DEPOSITION RATES



477% INCREASE in metal deposited with carbon dioxide

puts down metal at rates

½ lb. per minute!

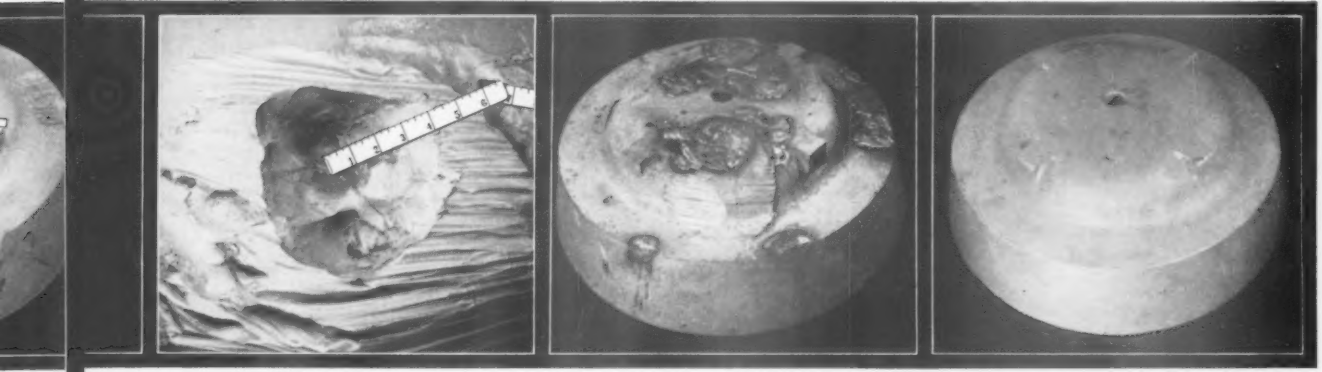
with A. O. Smith C-OMANUAL

When it comes to building up blowholes and other imperfections in castings, foundries are "sold" on C-OMANUAL. They're putting down metal at rates up to 30 lbs. an hour where with previous methods they put down three to five lbs. per hour.

Fast, easy, accurate — With C-OMANUAL, the operator works with a light-weight, perfectly balanced hand gun. He has the advantages of visible arc welding — spotting the nozzle's a cinch. And there's no flux to clean, no chipping, no scraping necessary. You can start at the bottom and work right to the top — without stopping. The C-OMANUAL control console automatically adjusts arc length too . . . compensates for distance variations.

Uses lowest cost gas — With C-OMANUAL, the carbon dioxide for shielding the arc costs only one cent per cubic foot and uses approximately 30 cubic feet per hour.

Seeing is believing — For complete details on how C-OMANUAL is helping foundries get an entirely new concept of low cost and high speed in casting salvage — contact your "man from A. O. Smith." He'll be happy to arrange for a demonstration, let you judge for yourself why C-OMANUAL is one of the "hottest" new advances in welding history!



Closeup of typical crater to be filled — diameter approximately 7 inches . . . depth 4 inches.

Rebuilt casting before grinding. Note absence of slag. Deep penetration and weld quality are assured.

Completed casting. On jobs such as this, C-OMANUAL puts down weld metal at least 5 times faster than conventional electrodes.

COST TO DEPOSIT 100 LBS. OF WELD METAL

	SEMI-AUTOMATIC C-OMANUAL (CO_2)	E-6013 HAND ARC
ELECTRODE WIRE	$29.07 (.285)	$20.80 (.135)
POWER	1.54	4.95
GAS	1.71	
WELD LABOR (3.00 per hr.)	17.10	99.00
BURDEN (5.00 per hr.)	28.50	165.00
TOTAL	$77.92	$289.75

A saving of $211.83 for each 100 lbs. of weld metal deposited

Through research A.O. Smith *. . . a better way*

A.O.Smith

CORPORATION

WELDING PRODUCTS DIVISION

Milwaukee 1, Wisconsin

International Division: Milwaukee 1, Wisconsin

New Members

Effective February 1, 1957

MEMBERSHIP CLASSIFICATION

A—Sustaining Member B—Member C—Associate Member

D—Student Member E—Honorary Member F—Life Member

Total National Membership

Sustaining Members	133
Members	5,844
Associate Members	6,249
Students	204
Honorary Members	8
Life Members	15
Total	12,453

ALBUQUERQUE

Gonzales, Max A. (C)

ANTHONY WAYNE

Jacobs, Fayette (B)

BATON ROUGE

Cox, Clayton C. (C)

BIRMINGHAM

Barker, William H. (B)
Sessions, Paul T., Jr. (B)

BOSTON

Allen, Earle F. (B)
Donohue, Paul E. (C)

BRIDGEPORT

Barker, Joseph E. (B)

CANADA

Dowding, Frederick C. (B)

CHATTANOOGA

Puryear, Ray (B)

CHICAGO

Johnston, Robert T. (B)
Klein, Rupert (C)
Lutes, Herbert L. (C)
O'Leary, Carl A. (B)
Wieser, Clarence J. (B)
Wright, Donald G. (C)

CINCINNATI

Burton, Edwin (C)
Fuller, Atwood L. (C)

CLEVELAND

Boyd, Richard M. (B)
Coates, Gilbert W. (B)
Davis, James J. (B)
Harder, William B., Jr. (C)
Kay, Leslie (B)
Milligan, Richard V. (C)
Perkins, Leigh H. (B)
Scheible, Roland A. (B)
Sherman, Emmett B. (C)
Snyder, Fred B. (C)
Stein, William F. (C)
Stiffler, Allen D. (C)
Taylor, Stevenson M. (C)
Valore, Joseph P. (B)
VanEpp, Franklin A. (C)
Zivkovich, Edward A. (B)

COLORADO

Fabry, J. W. (B)

COLUMBUS

Dixon, Leroy B. (B)
Spaniol, G. William (B)

DALLAS

Hanna, Oliver Kennith (B)
Stephens, William G. (B)

DETROIT

Collom, Donald J. (B)
Dec, Frank S. (C)
Denning, Erwin E. (B)
Gabriels, Stanley F. (B)
Green, Frank W. (B)
Groening, Robert E. (C)
Kelly, Frederick J. (C)
Oliphant, Lester E. (B)
Sheffield, Roy B. (B)
Sundeen, Melvin L. (C)
Tyler, Robert M. (B)

EAST TEXAS

Arp, Forrest F. (C)
Brittain, James G. (C)
Howell, R. B. (C)
Williams, Temple U. (C)

HOUSTON

Demecs, G. G. (C)
Dunibant, James E. (B)
Grove, James R. (C)
Opran, Torgor Albert (B)
Prince, Alton R. (C)
Willard, James L. (B)

INDIANA

Case, Coyle W. (B)
Kuester, Robert E. (C)

IOWA

Brolin, Charles A. (D)
Campbell, Angus (C)
Goetzen, Richard E. (C)
VanZomeren, C. J. (D)

IOWA-ILLINOIS

Young, James W. (B)

KANSAS CITY

Cobb, James B. (B)
Davis, Norris W. (B)
Fitzjarrell, Roy V. (B)

LEHIGH VALLEY

Brubaker, Enos H., Jr. (C)
Doughty, Sam (C)
Ferhafer, George W. (B)
Lawrence, William Howard (B)

LONG BEACH

Colter, Thomas A. (B)
Lewis, Charles D. (D)
Morales, Raul G. (D)
Ratermann, Andrew L. (C)
Smith, Terrell H. (D)
Storm, David C. (C)
Williams, Gordon L. (C)
Wilson, Eugene W. (B)

LOS ANGELES

Beams, James J. (D)
Byers, John Douglas (C)
Chaney, Clarence F. (C)
Collin, A. L. (B)
Finn, Marvin H. (B)
Goebel, Lee (B)
Grenier, John (B)
Huffman, Raymond L. (C)
Jenkins, Richard H. (B)
Jones, Ed S. (C)
Kairot, W. J. (B)
Ketchum, Cliff (D)
Krom, Rudolph J. (D)
Larsen, Irvin P. (B)
Lewis, John W. (C)
Lukehart, John M. (C)
Mandel, Albert (C)
McDonell, Thomas L. (D)
Meyers, John T. (C)
Miller, James A. (D)
Morgan, Benjamin, Jr. (C)
Murray, Donald C. (B)
Muser, Carl J. (B)
Newcomb, Leroy (B)
Phelps, Melvin Lee (B)
Quinn, H. J. (B)
Rasmussen, Frankee (B)
Reed, H. E. (B)
Reff, Thomas G. (C)
Schwab, A. C. (B)
Strong, George W. (C)
Syfers, William R. (C)
Turner, Kenneth G. (D)
Walmsley, J. Truman (C)
Warner, William Martin (D)
Williams, Fred T. (B)
Worden, William W. (D)
Zarro, Emil M. (D)
Zwissler, Charles A. (B)

LOUISVILLE

Erich, Earl A. (B)

MADISON

Jonas, Hymen (D)
Soderlund, Alf (C)
Topliss, Dallas J. (B)

MAHONING VALLEY

Fogel, John A. (B)
Glass, Jack L. (B)
Teter, Clarence L. (C)

MARYLAND

Kessler, Kenneth K. (B)
Mueller, John J. (C)
Winkler, Lawrence B. (C)

MICHIANA

Gorman, Richard A. (C)
Lauver, Claude (C)

MILWAUKEE

Burrmann, Lawrence F. (C)
Cech, Stanley (C)
Kirk, Donald A. (B)

NEBRASKA

Anderson, Kenneth W. (C)
Page, Dale (C)
Scribante, A. J. (C)

NEW HAMPSHIRE

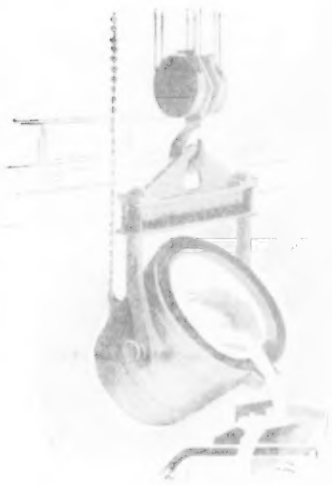
Dorr, Howard A. (C)
Fellows, Arthur L. (C)
Garland, Richard R. (B)
Kirwin, J. Raynor (C)
Kosiba, Stanley (B)
Pierce, Ernest L., Jr. (B)

NEW JERSEY

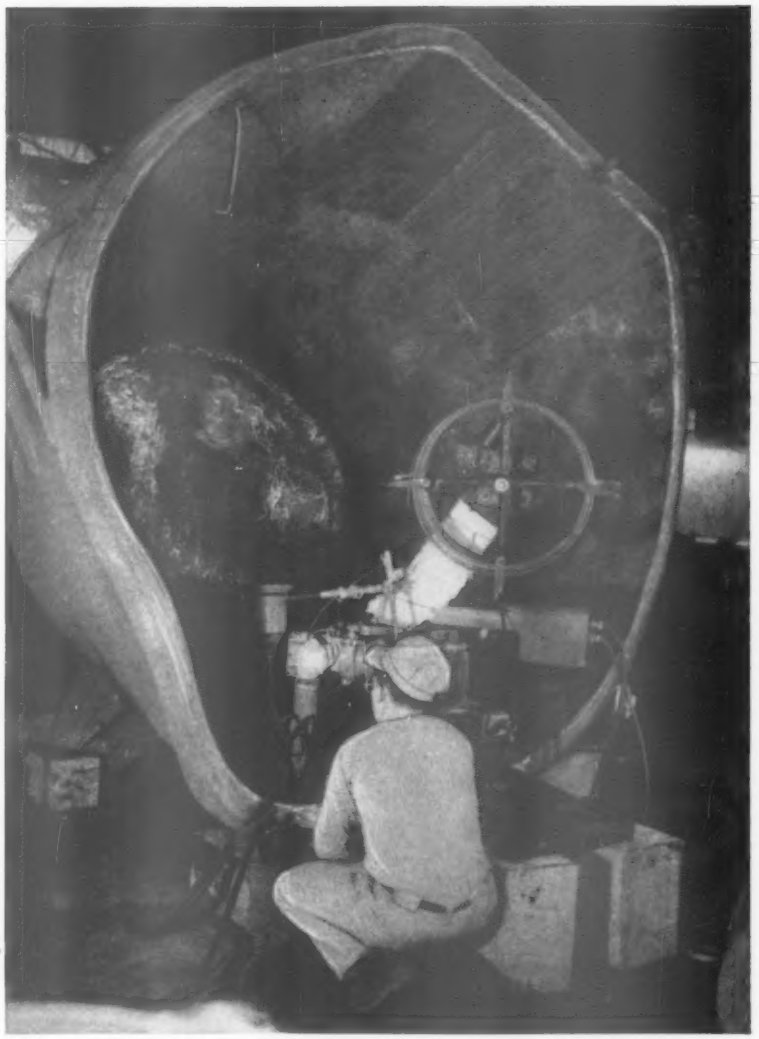
Avila, Arthur J. (B)
Dvorsky, Joseph G. (C)
Erlandson, Roy M. (B)
Kubli, Robert A. (B)
Rath, Howard G. (B)
Simkovich, John (C)
Spinelli, Carmen F. (C)
Wanamaker, Charles H. (C)
Zagata, Walter (B)

NEW ORLEANS

Bourgeois, Hudson M. (B)
Levy, Milton L. (B)



Erosion From Molten Copper Reduced 300%



23-Ton Ladle Protected With HASCROME rod by Submerged-Arc Method

The hard-facing operation shown above will increase the service life of this cast steel ladle by as much as 300 per cent. The material being applied is HASCROME rod . . . a high chromium alloy that effectively resists the destructive chemical action of molten copper. The alloy is deposited on the bottom and spouts of the ladle . . . the areas most vulnerable to erosion during pouring operations.

Despite the size of the ladle . . . 6 ft. high and about 8 ft. in diameter . . . the facing operation was accomplished rapidly. Coiled rod, applied by mechanized submerged-arc equipment, was used to cover the bottom and the spouts of the ladle. Facing speed averaged 7 inches per minute. Manual metallic-arc equipment and 14-in. long coated rods were used to face the contours around the spouts.

HASCROME rod, used so successfully here, is an iron-base material that also excels in applications requiring a tough, abrasion-resistant alloy. It has outstanding resistance to impact and sudden shocks.

There are 19 HAYNES hard-facing alloys . . . a wide selection that guarantees you the right rod at the right price for your wear problem. They all can be deposited with standard welding equipment. For descriptive literature on the complete line of HAYNES rods, contact your nearest Haynes Stellite Company office.

HAYNES TRADE-MARK ALLOYS

HAYNES STELLITE COMPANY

A Division of Union Carbide and Carbon Corporation

UCC

General Offices and Works: Kokomo, Indiana

Sales Offices

Chicago • Cleveland • Detroit • Houston • Los Angeles • New York • San Francisco • Tulsa

"Haynes" and "Hascrome" are registered trade-marks of Union Carbide and Carbon Corporation.

NEW YORK

Alesh, Boyan S. (B)
Blackman, Paul (C)
Burner, William N. (C)
Coleman, John H. (B)
Dubin, Lester (B)
Kavanagh, Thomas C. (B)
Kinney, C. M. (B)
Meylach, Sol (B)
Nacey, Henry (B)
Noble, Robert Edward (C)
Trust, Sydney S. (C)
Tsai, Chiu-Chin (B)

NIAGARA FRONTIER

Arnold, Dale (C)
Batt, Charles W. (B)
Damon, Lloyd E. (C)
Fricke, Warren C. L. (C)
Hawks, Burdette H., Sr. (B)
Ketterl, John J. (B)
Kloc, Longin (B)
MacLean, George N. (C)
McIvor, Joseph W. (C)
Neff, E. C. (C)
Schulenberg, Eugene (B)
Stadler, Raymond A. (C)
Teemley, Herman (A)
Zgoda, Raymond J. (C)

NORTH CENTRAL OHIO

Debo, Russell L. (C)
Griffith, Jack V. (C)
Mitchell, Howard M. (C)

NORTHEAST TENNESSEE

Caughron, Avery O. (B)
Cleuenger, D. J. (B)
Guinn, Jack C. (C)
Justus, A. D. (B)
Massengill, J. A. (C)
Tyl, Henry J. (C)
Wells, Glenn V. (B)
Woody, Kenneth W. (B)

NORTHERN NEW YORK

Leclair, Guy A. (C)
McVey, J. S., Jr. (B)

NORTHWEST

Engquist, Chester A. (B)
Gillaspy, Edward V. (B)
Hammer, Carl O. (B)
Lyons, Victor J. (B)

NORTHWESTERN PA.

Aleksa, Stanley (C)

OKLAHOMA CITY

Graybill, Roy (B)
Sherman, John Charles (C)

PHILADELPHIA

Carey, Clarence E. (B)
Case, C. R. (B)
Evans, Samuel R. (C)
Hallman, George E. (C)
Labosky, John W. (B)
McKenzie, Robert (C)
Weisel, Harold M. (B)

PITTSBURGH

Allison, F. H., Jr. (B)
Betz, Bruce F. (B)
Dalton, Ira B. (B)
Love, Robert E. (C)
Williamson, Robert (B)

PORTLAND

Watt, Harvey M. (C)

PUGET SOUND

Brown, Clark (C)
Carnwath, James R. (C)
Query, Ross H. (C)
Shipley, Alexander (C)

SAGINAW VALLEY

Johnston, Willis T. (C)
Stewart, Robert M. (B)

ST. LOUIS

Congemo, Sam (C)
Duke, James P., Jr. (B)
Gowan, Willard E. (B)

SAN ANTONIO

Alcorn, Joe D. (B)

SAN FRANCISCO

Jones, James K. (D)
Judnich, John F. (D)
Leader, Cliff (B)
Massey, Clarence W. (C)
O'Connell, Joseph A. (C)
Sohl, Henry W., Jr. (C)

SANGAMON VALLEY

Foster, Charles E. (C)
McHugh, James P. (B)

SANTA CLARA VALLEY

Adrian, Robert A. (B)
Haggett, Paul (B)

SHREVEPORT

Horton, John L. (B)
Ritchey, Nelson J. (B)

STARK CENTRAL

Brainerd, Robert A. (C)
Caldwell, Clarence J. (C)
Fair, Frank L. (C)
Gilbert, Fred (B)
Gussett, George, Jr. (C)
Halter, Herman J. (C)
Heestand, D. W. (C)
Kline, Hilary H. (C)
Latham, Russell (B)
Pfabe, Leonard C. (B)
Taylor, Robert L. (C)

SYRACUSE

Haun, Kenneth L. (C)

TRI-CITIES

Waninger, Norman (B)

TULSA

McSherry, Francis M. (B)
Sessing, Ralph E. (C)

WESTERN MASSACHUSETTS

Fairbanks, Donald R. (C)
Trombley, Raymond G. (C)

WESTERN MIGHIGAN

Leazenby, Edward E. (B)

WORCESTER

Grady, Edward F. (B)
Kranz, Edward L. (B)
Perry, Lorenzo E. (B)

YORK-CENTRAL PA.

Bates, James T. (C)
Koretzky, Heinz P. (B)

NOT IN SECTIONS

Barajas, Luis Cuevas (C)
Glombitza, Helmut (C)
Straub, Damian (B)

Members Reclassified

During the month of February

CHICAGO

Becker, Wilfred E. (C to B)
Root, Wilbur B. (C to A)

CINCINNATI

Rouff, Kenneth R. (C to B)

DETROIT

McEnally, V. L., Jr. (C to B)

HOUSTON

Ragone, Louis A., Jr. (C to B)

LONG BEACH

McAllister, Eugene (C to B)

MILWAUKEE

Banfay, Stephen (D to C)
Fisher, Robert J. (B to A)
Garriott, F. Emery (C to A)
Monsler, Melvin O. (C to A)
Welch, Jerome (B to A)

PUGET SOUND

Sweek, Alex D. (C to B)

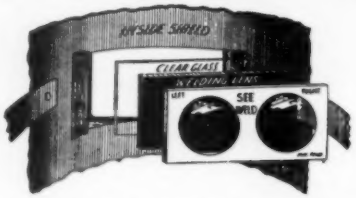
ST. LOUIS

Brauss, Norman W. (C to B)
Polick, Isaac L. (C to B)

SAN ANTONIO

Lowrey, John T. (C to B)
Patrick, Royce A. (C to B)

SEEWELD - MAGNIFYING - PLATES



PROVIDE BETTER VISION FOR WELDERS

Most welders past the age of 38 to 40 years need spectacles for close work and while welding but, as every welder knows, it is impossible to wear them under goggles or helmets.

To overcome this difficulty Seeweld Plates were designed. They are plastic plates in which are inserted optical glass lenses of varying magnifying powers. These are placed in goggles or helmets and take the place of spectacles.

SEEWELD Plates come in eight different magnifying powers and following is a table which enables welders to select, according to age, the magnifying power needed to secure clear, distinct vision without the use of spectacles.

Age to 41 years	Seeweld A	Age 50 to 52 years	Seeweld E
" 41 to 44 "	" B	" 52 to 54 "	" F
" 44 to 47 "	" C	" 54 to 56 "	" G
" 47 to 50 "	" D	" 56 and over	" H

Seeweld Plates are carried in stock by many Welding Equipment distributors but if yours does not handle them, write to us direct. The price is $5.00 each.

To Distributors: Dealers who handle Seewelds make friends of welders because frequently experienced welders find it difficult to hold or secure employment due to their age which has resulted in a normal loss of vision at near point. Seewelds restore vision to normal and age therefore is no handicap. "Sell A Seeweld and help a welder." Send for Dealers Proposition.

THE BUELL W. NUTT CO.

11614 WEST PICO BLVD., LOS ANGELES 64, Cal.

Get the BEST for LESS
Get
"ANTI-BORAX" FLUXES
Fully Guaranteed

SAFE—NON-TOXIC

No. 1	Cast Iron Welding Flux
No. 2	Brazing Flux
No. 4	"Braz-Cast" Flux for bronze welding cast iron
No. 8	"ABC" Sheet Aluminum Flux
No. 16	Silver Solder Paste Flux

Send for complete Folder and Samples

Mfg. by
ANTI-BORAX COMPOUND CO. INC.
Fort Wayne 9, Indiana

LIGHTWEIGHT

WELDING CABLE!

Made of Kaiser Aluminum— one-third lighter than copper!

Greatly reduces fatigue—Easier to lift and drag around . . . an important factor in reducing fatigue, increasing job efficiency.

Makes work easier—To demonstrate flexibility, it can be looped into a small circle with thumb and forefinger.

Tough GRS rubber or Neoprene jacket—Resists abrasion, acids, sunlight and heat. Neoprene jacket is flame-resistant and impervious to oils and greases.

Simple connections—Takes good mechanical and soldered connections—either aluminum to aluminum or aluminum to old copper cable.

Saves money—The favorable price of aluminum, when compared to copper, provides important economies.

Install aluminum whip-leads now! Until your copper cables come up for replacement, your existing copper lines can easily be equipped with light, flexible aluminum whip-leads by means of simple mechanical connections. Weldors can tell the difference immediately! And as your copper cables are ready for replacement, you can take full advantage of aluminum for the entire line.

For complete information on new aluminum welding cable, contact your welding equipment manufacturer or your nearby welding supply distributor. Aluminum welding cable is produced for equipment manufacturers by Kaiser Aluminum at the company's Newark, Ohio wire and cable mill.

Whip-lead of Kaiser Aluminum welding cable with Twecotong Al-300 forged aluminum electrode holder and Tweco Me-Con connector by Tweco Products, Wichita, Kansas.

Kaiser Aluminum is a leading producer of electrical conductor for transmission, distribution and service drop lines. In addition, Kaiser Aluminum produces building wire and other aluminum conductor products for industry.

At your request, we will be glad to send you our informative folder, "New Advantages in Arc Welding Cable with Aluminum Welding Cable." Write to Kaiser Aluminum & Chemical Sales, Inc., *Executive Office,* Kaiser Building, Oakland 12, California; *General Sales Office,* Palmolive Building, Chicago 11, Illinois.

IF IT CARRIES CURRENT, K/W CARRIES IT!

Kaiser Aluminum

See "THE KAISER ALUMINUM HOUR." Alternate Tuesdays, NBC Network. Consult your local TV listing.

Current Welding Literature

For copies of articles, write directly to publications in which they appear

Accident Prevention. Protective Clothing for Welders. *Brit. Standards Instn.*—Brit. Standard, no. 2653 (1955), 11 pp.

Automobile Manufacture. Making Volkswagen. *Machy.* (Lond.), vol. 89, no. 2287, (Sept. 14, 1956), pp. 604–619; no. 2291 (Oct. 12), pp. 828–838; no. 2292 (Oct. 19), pp. 884–891; no. 2293 (Oct. 26), pp. 950–953.

Brazing. Dip Brazed Parts Take Heat. *Steel*, vol. 139, no. 15 (Oct. 8, 1956), pp. 114–115.

Brazing. Gas-Fired Machine Brazing, W. B. Troupe. *Steel*, vol. 139, no. 18 (Oct. 29, 1956), pp. 124–127.

Brazing. High Temperature Brazing of Gas Turbine Components, J. V. Long, G. D. Cremer and R. S. Mueller. *Soc. Automotive Engrs.* (Paper no. 829 for meeting Oct. 2–6, 1956), 10 pp.

Brazing. Nickel-Manganese Brazing of Steel, R. A. Gustafson. *Welding & Metal Fabrication*, vol. 24, no. 8 (August 1956), pp. 290–291.

Diesel Engine Manufacture. Fabrication of Welded Steel Crankcase for Large, 2-Cycle Diesel or Natural Gas Engine, L. L. Young. *General Motors Eng. Jnl.*, vol. 3, no. 4 (July-August-September 1956), pp. 22–27.

Electric Arcs. Influence of Atmospheric Water Vapor on High-Current D-C Arcs, R. H. Benner, II and T. B. Jones. *Am. Inst. Elec. Engrs.—Trans.*, vol. 75, pt. 2 (Applications & Industry), no. 25 (July 1956), pp. 162–166.

Electrodes. New Plant for Electrode Production, P. R. Simpson. *Welding & Metal Fabrication*, vol. 24, no. 8 (August 1956), pp. 292–295.

Floors. Open Steel Flooring, S. K. Sarkar. *Instn. Engrs. (India)—Jnl.* vol. 36, no. 1, pt. 2 (September 1955), pp. 1143–1151.

Inert-Gas Welding. Experiments with Carbon Dioxide Shielded Welding of Mild Steel, R. E. Jahn and L. M. Gourd. *Welding & Metal Fabrication*, vol. 24, no. 10 (October 1956), pp. 368–376.

Iron Castings. Brittle Failure of "Bronze" Welds, G. E. Morton. Brit. Cast Iron Research Assn.—*Jnl. Research & Development*, vol. 6, no. 8 (October 1956), pp. 403–408, 10 plates.

Iron Castings. Welding of Flake Graphite Cast Irons, with Particular Reference to Mechanical Properties of Butt-Welded Joints, F. Dunn and G. E. Morton. Brit. Cast Iron Research Assn.—*Jnl. Research & Development*, vol. 6, no. 8 (October 1956), pp. 364–402, 16 plates.

Locomotive Manufacture. Building English Electric Locomotives. *Welding & Metal Fabrication*, vol. 24, no. 10 (October 1956), pp. 344–351.

Machine Tool Manufacture. Practical Design Techniques for Controlling Vibration in Welded Machines, M. Kronenberg, P. Maker and E. Dix. *Machine Design*, vol. 28, no. 14 (July 12, 1956), pp. 103–109.

Metal Cladding. Welding Composite Steels: Applied Liners, H. Thielsch. *Machine Design*, vol. 28, no. 15 (July 26, 1956), pp. 86–91.

Niobium. Niobium, F. G. Cox. *Welding & Metal Fabrication*, vol. 24, no. 10 (October 1956), pp. 352–358.

Nuclear Reactors. Fabricates Giant Reactor Vessel. *Steel*, vol. 139, no. 16 (Oct. 15, 1956), pp. 135–136.

Petroleum Refineries. Furnace-in-Sky Sets Pattern for Vessel Stress Relief, P. C. Arnold. *Petroleum Engr.*, vol. 28, no. 9 (August 1956), pp. C23–C24.

Pipe Lines. Consumable Solid Insert Rings Improve Pipe Welding Quality, H. Thielsch. *Heating, Piping & Air Conditioning*, vol. 28, no. 10 (October 1956), pp. 100–103.

Pipe Lines. Steam-Line Welds Improved by Backing-Ring Elimination, W. A. Pollock. *Elec. Light & Power*, vol. 34, no. 17 (August 15, 1956), pp. 86–90.

School Buildings. Welded Framing for Economical School Buildings, R. P. Saxe. *Civ. Eng. (N. Y.)*, vol. 26, no. 8 (August 1956), pp. 40–42.

Shipbuilding. How to Avoid Cracks in Welded Hulls, G. Vedeler, *Mar. Engr. & Naval Architect*, vol. 79, no. 960 (October 1956), pp. 352–354.

Shipbuilding. Shipbuilding in Japan with Particular Reference to Welding, R. Ibison. *Shipbldg. & Shipg. Rec.*, vol. 88, no. 19 (November 8, 1956), pp. 603–610.

Soldering. Designing for Soldered Joints, J. B. Mohler. *Machine Design*, vol. 28, no. 12 (June 14, 1956), pp. 123–128.

Solders. Photometric Determination of Copper in Aluminum and Lead-Tin Solder with Neocuproine, J. W. Fulton and J. Hastings. *Analytical Chem.*, vol. 28, no. 2 (February 1956), pp. 174–175.

Steam Pipe Lines. Welding High-Pressure Pipe Lines, J. E. Burton and J. N. Bradley. *Engineering*, vol. 182, no. 4725 (Sept. 28, 1956), pp. 399–404.

Submerged-Arc Welding. Automatic Submerged-Arc Welding of Alloy Steel, R. A. Wilson. *Metal Progress*, vol 70, no. 4 (October 1956), pp. 104–107.

Testing. Photoelectric Cells Detect Spotweld Flaws Automatically, H. Chase. *Iron Age*, vol. 178, no. 17 (October 25, 1956), pp. 114–115.

Titanium. Argon-Arc Welding of Commercially Pure Titanium, E. A. Taylor and D. C. Moore. *Welding & Metal Fabrication*, vol. 24, no. 8 (August 1956), pp. 268–280.

Titanium. Silver Brazing of Titanium, N. A. Tiner. *Sheet Metal Industries*, vol. 33, no. 354 (October 1956), pp. 707–712.

Titanium. Three Ways to Weld Titanium, J. W. Cunningham. *Steel*, vol. 139, no. 9 (August 27, 1956), pp. 84–86.

Titanium and Titanium Alloys. Properties of Titanium, R. L. Preece. *Sheet Metal Industries*, vol. 33, no. 353 (September 1956), pp. 633–635, 646.

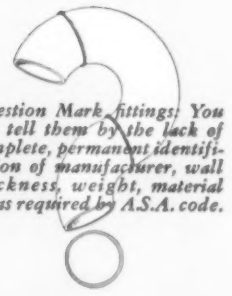
Training. Even Small Firms Can Train and Test Welders. *Welding Engr.*, vol. 41, no. 7 (July 1956), pp. 78, 80.

Water Heaters. Rheem Glass Lines Its Heaters. *Steel*, vol. 139, no. 16 (Oct. 15, 1956), pp. 124–125.

Welding. Distortion in Welding, W. T. Amison. *Welding & Metal Fabrication*, vol. 23, no. 12 (Dec. 1955), pp. 475–477; vol. 24, no. 2 (February 1956), pp. 63–64.

Welding. Paths to Increased Productivity in Fabrication, A. G. Thompson. *Welding & Metal Fabrication*, vol. 24, no. 9 (September 1956), pp. 308–312; no. 10 (October), pp. 377–380.

Why try to cut corners with *Question-Mark** fittings?



**Question Mark fittings: You can tell them by the lack of complete, permanent identification of manufacturer, wall thickness, weight, material . . . as required by A.S.A. code.*

Unknown welding fittings are as risky as unmarked turns on a busy highway. These blind spots in an expensive piping project cause slow-downs, confusion, trouble . . . waste time and money.

"Question Mark" fittings may look like a bargain on the price tag, but watch out for the after-costs . . . poor fit-up, impaired quality, questionable supply, lack of engineering service! Your reputation is at stake!

A message in the interests of top quality piping . . .
by Tube Turns, Louisville, Kentucky.

HOW TO SAFEGUARD YOUR REPUTATION

He knows he's getting the exact fitting specified on the blueprint because each TUBE-TURN product is clearly marked with all designations.

Save manhours...avoid piping risks with known fittings

You save purchasing time, get prompt delivery, speed up installation, and help assure reliable piping performance when you specify TUBE-TURN* Welding Fittings and Flanges. They meet all American Standard and Safety Code requirements. Each product is permanently marked with complete size and material designation. Your nearby Tube Turns' distributor gives you prompt delivery from the complete-line stock, and makes available Tube Turns' unmatched engineering service.

You *know* your piping investment is safeguarded when you specify and buy Tube Turns' products.

Your nearby Tube Turns' Distributor meets your needs promptly from the complete line of more than 12,000 Tube Turns' stocked items.

The Leading Manufacturer of Welding Fittings and Flanges

TUBE TURNS LOUISVILLE 1, KENTUCKY

A Division of National Cylinder Gas Company

DISTRICT OFFICES: New York • Philadelphia • Pittsburgh • Chicago • Detroit • Atlanta • New Orleans • Houston • Midland
Dallas • Tulsa • Kansas City • Denver • Los Angeles • San Francisco • Seattle

In Canada: Tube Turns of Canada, Ltd., Ridgetown, Ontario • Toronto, Ontario • Edmonton, Alberta

*"TUBE-TURN" and "tt" Reg. U. S. Pat. Off.

NEWS of The Industry

Airco Breaks Ground for New Los Angeles Plant

In ground-breaking ceremonies attended by civic and industrial leaders from the Los Angeles and San Francisco areas, the Air Reduction Pacific Co., a division of Air Reduction Co., Inc., on February 7th launched construction of a multi-million dollar air separation and liquefaction plant at Bassett, Calif., a few miles from the city of Los Angeles.

The new plant, which will be of completely modern design, will produce

daily 55 tons of high purity liquid oxygen, 15 tons of liquid nitrogen, and $3^1/_2$ tons of liquid argon. The cost of the plant, including related delivery facilities, will be in excess of $7,500,000.

Scheduled for completion late in the year, the new plant will serve primarily the aircraft, steel, metal fabricating, chemical and food processing industries in the California, New Mexico and Arizona areas.

When completed, the Los Angeles plant will be the fourth air separation and liquefaction plant to be constructed by Air Reduction. The company already operates such plants at Butler, Pa., and Riverton, N. J., and will soon complete construction of a large new facility at Chicago.

Motion Pictures

The United States Steel Corp. announces the availability of the 18th edition of a catalog describing educational and entertaining motion pictures sponsored and distributed by the company. This edition includes five new films released in 1956. They are available to all recognized trade, business and other associations in preparing programs for their members.

For a copy of catalog write to United States Steel Corp., Film Distribution Center, 525 William Penn Place, Pittsburgh 30, Pa.

Welderama and Open House

The Mineweld Co., 4565 DeTonty St., St. Louis 10, Mo., announces that it will hold a Welderama and Open House on May 1st through May 4th at its place of business. Company will feature live demonstrations of many phases of welding, plus several of the newer processes. Also, there will be a large display of welding equipment and supply accessories. Linde Air Products Co., Haynes Stellite Co. and Lincoln Electric Co. will feature with live demonstrations.

Compressed Gas Association Elects Dunham

Election of James W. Dunham of the National Cylinder Gas Co., Chicago, as president of the Compressed Gas Assn., Inc., was announced in New York on Feb. 13, 1957.

Mr. Dunham is vice-president of the National Cylinder Gas Co. in charge of industrial gas production, engineering

James W. Dunham

and research. He succeeds Merle L. Griffin of Shell Chemical Co. in the Association post.

Mr. Dunham, a past president of the International Acetylene Assn., graduated from Massachusetts Institute of Technology in 1926 and has been active since that time with NCG and its predecessor companies, founded by his father, the late M. Keith Dunham.

The Compressed Gas Assn. represents all segments of the compressed gas industry, playing an increasingly important role in the economy as new and broader uses induce an ever-expanding market for industrial gases.

Other new officials elected at the organization's 44th annual meeting were: first vice-president, A. R. Olson, Suburban Propane Gas Corp.; second vice-president, Claude E. Monlux, Linde Air Products Co.; and secretary-treasurer, F. R. Fetherston, re-elected.

M&T Relocates Atlanta Sales Offices

Metal & Thermit Corp., New York, has announced that, on March 1st its Atlanta, Ga., facility was moved to new quarters.

Sales offices are located at the Atlanta Service Warehouse, 565 Western Ave., N. W., Atlanta, Ga., where complete stocks of mild steel, alloy steel, stainless and hard-surfacing welding electrodes also are maintained.

Claude E. Davis, Jr., Southeastern Regional Manager of M&T's Welding Division continues to be in charge.

COMING EVENTS

A Calendar of Welding Activity

AWS National Meetings

1958 Spring Meeting and Welding Show:

April 14–18, Statler Hotel, St. Louis, Mo.

NWSA

May 13–16, 1957. Thirteenth Annual Convention, Hotel Mayflower, Washington, D. C.

ASM

Nov. 4–8, 1957. Thirty-ninth National Metal Exposition & Congress, concurrently with Second World Metallurgical Congress, International Amphitheatre, Chicago, Ill.

Wear Your AWS Emblem!

PROOF of how to get dependable results welding by submerged arc

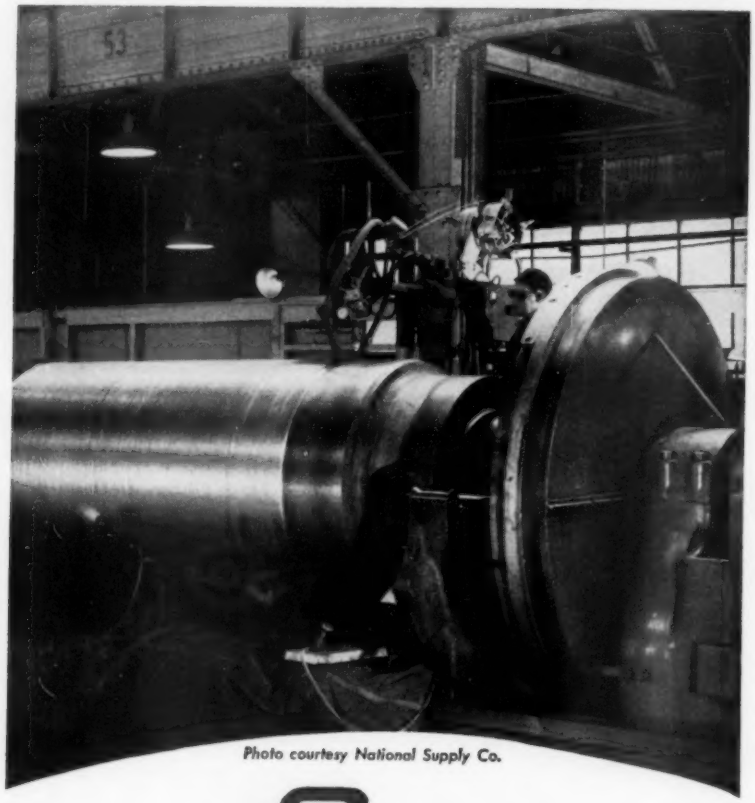
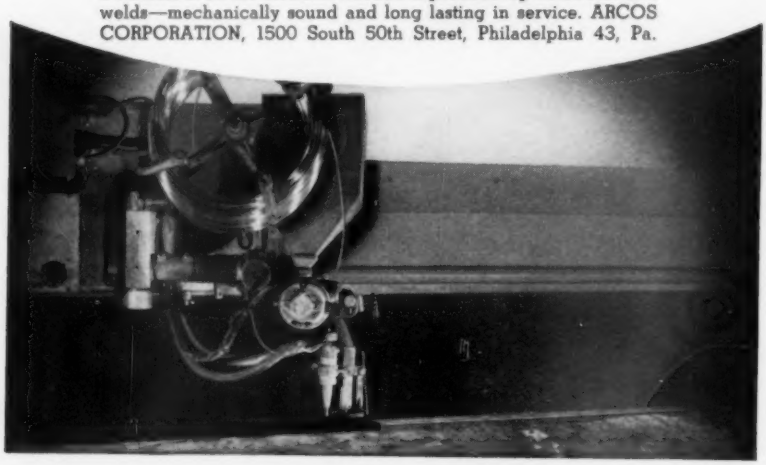


Photo courtesy National Supply Co.

WELD WITH ARCOS

STAINLESS COILED WIRE

Shown above is a 72,000 lb. Extrusion Ram being overlaid by submerged arc with type 316 stainless weld metal. At the conclusion of the job the entire extensive welded surface was reported sound and crack-free—the same results you can expect with Arcos Chromenar Wire on your own jobs. Arcos control of the composition of its Chromenar *welding quality* spooled wire assures a transfer of all the elements needed to produce top notch stainless welds—mechanically sound and long lasting in service. ARCOS CORPORATION, 1500 South 50th Street, Philadelphia 43, Pa.



Westinghouse Forms New Division

The formation of a new division of the Westinghouse Electric Corp. has been announced by W. W. Sproul, Jr., vice-president in charge of general products.

To be known as X-ray and industrial electronics division, the new unit represents a merger of the X-ray division and the industrial electronics department, both of which have been located in Baltimore, Md. The industrial electronics department has been a Baltimore operation of the company's industrial heating division whose headquarters are located at Meadville, Pa.

At the same time, Mr. Sproul has announced that W. J. Delaney, Jr., formerly manager of the welding department, motor and control division, Buffalo, N. Y., would head the X-ray and industrial electronics division. H. D. Moreland and R. C. Cheek will continue as managers of the X-ray and industrial electronics operations, respectively.

Lincoln Electric Announces Appointments

The Lincoln Electric Co. announces new assignments for Richard N. Stratton, Roy E. Williams and Marshall H. Ford.

Mr. Stratton is now District Manager of the Charlotte, N. C., area. Prior to his new assignment, he was a welding engineer for The Lincoln Electric Co. in Baltimore and, earlier, Washington. Graduated from Virginia Polytechnic Institute with a B.S. in Metallurgical Engineering in 1942, he served with the Air Force in the United States and Southwest Pacific as a pilot. Mr. Stratton returned to civilian life in 1946 and worked for Airports Airways Associates and Luscombe Airplane Corp. before joining Lincoln in 1949.

Mr. Stratton is active in technical societies, being a member of the American Society of Metals, and past secretary and executive committeeman of the Washington Section of the American Welding Society.

Mr. Ford has been appointed District Manager of the Duluth, Minn., area. He moves to Duluth from Minneapolis where he was succeeded by Roy Williams. Mr. Ford graduated from Western Reserve University in 1939 with an A.B. degree. He worked for Inland Steel before joining Lincoln in 1941. His first assignment with Lincoln was in Pittsburgh, Pa., from 1941 to 1947. He is a past executive committeeman of the Minneapolis Section of the American Welding Society.

Mr. Williams, in assuming the posi-

tion of district manager, moves up in the same office in which he has been a welding engineer. A native of Minneapolis, he attended local schools and was employed by the Hamilton Construction Co. and the National Bushing and Parts Co. in Minneapolis before joining Lincoln in 1939. Mr. Williams has been a member of the Minneapolis Section of the AMERICAN WELDING SOCIETY since 1937.

ABS Elects Officers

The 95th Annual Meeting of the Board of Managers and the Members of the American Bureau of Shipping was held on January 29th in the Bureau's Board Room, 45 Broad St., New York City.

Walter L. Green, who previously has been both chairman of the Board of Managers and president, was re-elected as chairman of the Board, and David P. Brown, formerly senior vice-president and technical manager, was elected president of the Bureau.

Jerome B. Crowley, formerly vice-president, Finance and Administration, was elected senior vice-president.

Lewis C. Host, formerly chief surveyor, was elected vice-president—operations and Arthur R. Gatewood, formerly chief engineer surveyor, as vice-president—engineering.

Alfred Blum was re-elected treasurer and Daniel L. Parry was re-elected secretary.

Re-elected as assistant vice-president was Harold M. Wick, Kurt Molter as assistant treasurer and William H. C. Seelig as assistant secretary.

The Messrs. Green, Brown, Host and Gatewood are members of the AMERICAN WELDING SOCIETY.

Bridge Design Competition

The James F. Lincoln Arc Welding Foundation of Cleveland, Ohio, has announced a new bridge design competition offering a total of $50,000 in awards for designs of welded highway bridges. The awards will be made to the best designs submitted for highway bridges that are or could become a part of the National System of Interstate and Defense Highways. Any type of bridge either built or proposed can be submitted so long as it conforms to the general requirements of the Interstate and Defense Highway System. A total of 16 awards will be made with a top award of $10,000. Designs will be judged on quality of detail, economy in material and labor, cost savings and appearance.

The new competition, the fourth in a series sponsored by the Foundation, is open to all residents of the United States or its possessions. Information

HOW TO GET WELDED SECURITY ON THE MOST CRITICAL JOBS

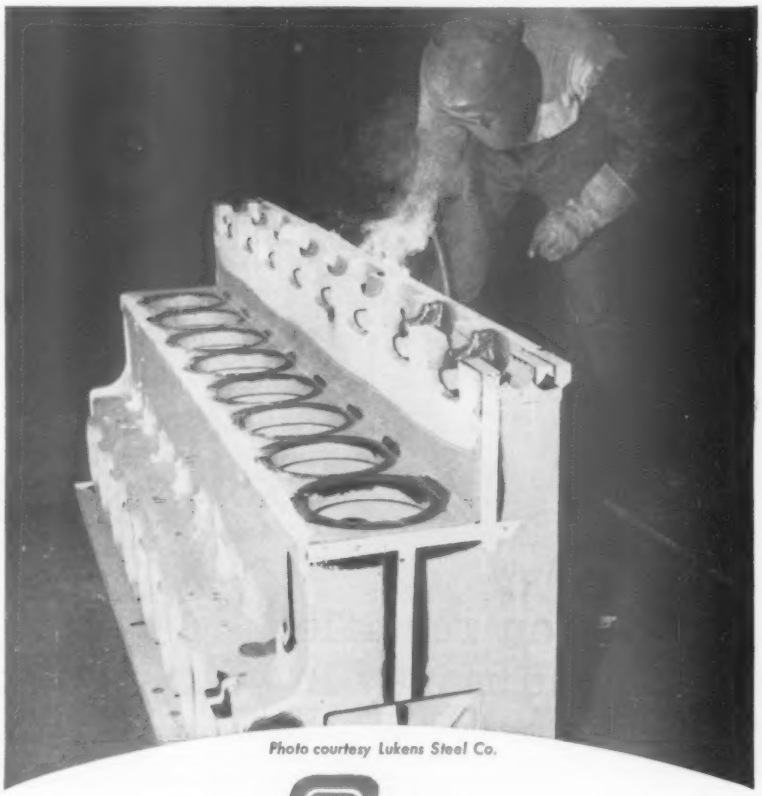


Photo courtesy Lukens Steel Co.

WELD WITH ARCOS

STAINLESS ELECTRODES

This Diesel engine housing—for use on a mine sweeper—is a new application for welded *stainless*. 18-8 stainless was selected for its non-magnetic properties. The unit, and many others, were completely welded with Arcos E308HC-15 low magnetic permeability coated electrodes. Why Arcos? For a reason you'll want to keep in mind: When base metal properties are critical . . . and performance requirements exacting, Arcos quality assures sound weld metal for lasting security. ARCOS CORPORATION, 1500 South 50th Street, Philadelphia 43, Pa.

on the preparation of entries may be obtained from The James F. Lincoln Arc Welding Foundation, Cleveland 17, Ohio.

Staff Changes Announced by ABS

The American Bureau of Shipping has announced the following changes in the Technical Staff at the New York headquarters, effective Feb. 5, 1957.

Ralph C. Christensen, formerly chief surveyor—Hull, has been appointed chief surveyor to succeed Lewis C. Host, recently elected to the position of vice-president—Operations.

David B. Bannerman, Jr., formerly assistant chief surveyor—Hull, has been appointed chief surveyor—Hull.

John W. Heck, formerly assistant chief surveyor—Engineering, has been appointed chief surveyor—Machinery to succeed Arthur R. Gatewood, recently elected to the position of vice-president—Engineering.

All appointees are members of the American Welding Society.

Prize Contest for Oxyacetylene Welding

The Ill-Mo Welding Products Co. of Jacksonville, Ill., has announced its sponsorship of a new oxyacetylene welding contest open to all high-school students in 35 counties in Central Illinois and Northeast Missouri. The scope is to stimulate interest in welding among high-school students and to provide an additional incentive for them to improve their welding skill.

Welded articles submitted in the contest must fit one of the two following divisions (1) articles, objects or furnishings for the home, yard or garden; and (2) useful articles, tools or equipment for farm or shop.

Separate prizes will be awarded in each of these two divisions—first, $50 Savings Bond; second, $25 Savings Bond. A grand prize consisting of a complete "all-purpose" welding and cutting outfit, with a retail value of $76.50, will be awarded to the student who submits the most unusual and original oxyacetylene welded article in either division.

All articles in competition must have been completed within the 1956–57 school year. They must be submitted to and will be judged at the Ill-Mo Welding Products Co. tent at the 1957 Illinois State Fair in Springfield, Ill., on August 9th to 18th.

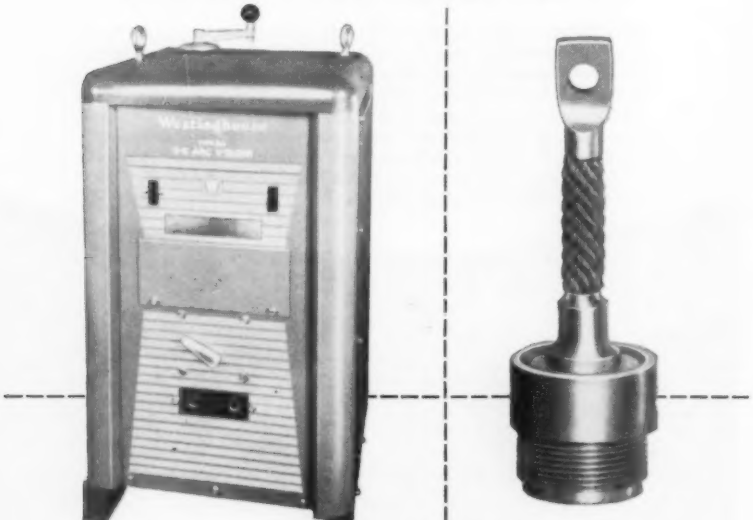
Members of the staff of the University of Illinois Vocational Agricultural Service will judge the contest.

Complete details may be had by writing to Ill-Mo Welding Products Co., 120–142 Dunlap Court, Jacksonville, Ill.

The new silicon rectifier means money in your pocket

. . . money you'll save because this revolutionary Westinghouse welding development has been proved by industry to be the most efficient, most durable ever offered. It's hermetically-sealed against dust, oil, water and acid fumes. And for the welding operator there's excellent performance — easier arc starting, better arc stability, maximum drive.

The new silicon rectifier is another milestone in welding, another Westinghouse *plus* that teams with "wide-amp" control and "arc-drive" control to bring you the *best* in welding equipment. J-21983



YOU CAN BE SURE...IF IT'S

Westinghouse

OKI Welding Celebrates 20th Anniversary

In March 1957, OKI Welding Supply Co, Cincinnati, Ohio, celebrated the 20th Anniversary of its founding.

The organization started as a partnership between A. B. Caluwaert and E. C. Caluwaert. Since Mrs. Caluwaert passed away in September 1955, the organization has been operated as a single proprietorship by E. C. Caluwaert.

The organization specializes in the sale of welding equipment and supplies. Ten full-time salesmen are employed. A retail department is maintained for sales in the metropolitan Cincinnati area. A wholesale department is maintained and operates in Michigan, Indiana, Ohio, Kentucky and West Virginia.

New GE Sales Office

A new warehouse and sales office has been established at Birmingham, Ala., by General Electric's Welding Department, it was announced recently.

Douglas A. Hopper, general manager of the Welding Department, said that establishment of the warehouse and office will augment dealers in the Birmingham area.

The new facility will be directed by I. F. Dorrell, Sales Supervisor. It is located at 130 W. Finley Ave., Birmingham.

New Hobart Distributor

Valley Welding Supply, Inc., 1828 W. Wisconsin Ave., Appleton, Wis., has been appointed a distributor for Hobart Bros. Co., Troy, Ohio. The new distributor will handle the complete line of Hobart Welding Equipment and electrodes in northern Wisconsin. Principals of the company are three brothers, Ed, Bill and Bob Hart, who have been in the welding supply business for eight years.

Eutectic Plans New Plant in Brazil

Plans are complete, and equipment will be installed in the near future, for a new plant in São Paulo, Brazil, for the manufacture of a wide variety of metal-joining alloys and fluxes, according to an announcement by Rene D. Wasserman, president of Eutectic Welding Alloys Corp.

The manufacturing facilities will consist of equipment for the production of welding electrodes and gas rods, as well as brazing alloys, solders and fluxes.

Aside from the production equipment, the new plant will house a fully equipped laboratory not only for testing but also for research and development of new products. There will also be a special room and equipment for Eutectic's Welding Institute.

The new plant is expected to be in full operation early this Spring.

Distributors Appointed by Alloy Rods

E. R. Walsh III, vice-president in charge of sales of Alloy Rods Company, announced recently the appointment of the following distributors to the Alloy Rods Co. distributor organization: California Welding Gases, Inc., Salinas, Calif.; Norco Welding Equipment & Supplies, Boise, Idaho; and Sierra Oxygen Co., Reno, Nev.

Good 1957 Forecasts in Resistance Welding

The monthly statistical report compiled by the Resistance Welder Manufacturers' Assn. indicates net orders received during January have increased 73% over December.

Shipments during January again exceed $3 million for the sixth month out of the last seven, and reflect an increase of 16% over January of last year.

Members reported a backlog of more than $12 million at the end of January, a figure which has held steady for several months.

long on service . . .
short on maintenance . . .
just right
on cost!

#1834
(7 other sizes, too)

MANGANAL
T.M. REG. U.S. PAT. OFF.
11%-13½% MANGANESE-NICKEL STEEL
MILL LENGTH
HOT ROLLED
WEDGE BARS

- T4 to 18 foot bars mean less scrap loss.
- Can be bent hot or cold.
- No defects common to castings.
- Long lengths for bucket lips, grizzly bars, etc.

STULZ-SICKLES CO.
SOLE PRODUCERS 929-39 PORT AVE. • ELIZABETH, N. J.
NEAREST DISTRIBUTOR UPON REQUEST

AT THE FRONTIERS OF PROGRESS YOU'LL FIND

AN AIR REDUCTION PRODUCT

FOR WELDING AND CUTTING...

IN THE RED DRUM

HIGHEST QUALITY

DUST-FREE

NATIONAL CARBIDE

Write for the name and address of the NATIONAL CARBIDE supplier nearest you.

National Carbide Company
GENERAL OFFICES: 150 EAST 42ND STREET, NEW YORK 17, N.Y.
A DIVISION OF AIR REDUCTION COMPANY, INCORPORATED

INTERNATIONAL WELDING NEWS

Welding Research in the Soviet Union

Translation from the German
by Rudolph O. Seitz

(*Continued from March 1957 issue, p. 324*)

Some Institutes Visited by the German Delegation

The report of the German delegation describes in greater detail the activities of some of the most important institutes visited. The account is confined to two academy institutes, one university institute and two industrial laboratories.

I. "Imet"-Institute of Metals of the Academy of Science at Moscow

This institute was founded about 4 years ago and now has a staff of 1000, of which 700 are scientists and engineers. It is engaged in basic ferrous and nonferrous metallurgical research. Although it is independent of the Ministry for Mining and Metallurgy, its research programs are formulated after consultation with the research institutes operated by this ministry, and after successful completion of the programs, the results are handed over to this ministry for possible practical utilization.

Among the most important fields of interest are: the development of new grades of steel by various processes, with due regard for weldability; the application of vacuum in metallurgy; the development of new methods of desulfurization; the investigation of slags; and the development and improvement of a continuous casting process.

The laboratories of the institute are equipped with the most modern equipment, some of which has been specially designed by members of the staff. The work of the different sections is well integrated. The institute comprises the following special laboratories for research in: properties of metals at elevated temperatures; thermodynamics; fine X-ray structure; isotopes; high temperature measurement; nonmetallic inclusions; slag viscosity; blast furnace slags; blast furnace operation (with a small operating blast furnace); deoxidation of ores under pressure; nondestructive testing; fatigue strength and welding.

The work of the welding laboratory under the direction of Professor Rykalin is divided into two fields of endeavor: (*a*) determination of the weldability of the new steels developed at the institute; (*b*) fundamental investigations of the thermal processes connected with welding, and of problems of automatic welding.

The weldability section uses all the familiar testing methods and procedures, among them also the Schnadt, Cabelka and other tests. The work covers steels prepared by different methods, e.g., low-alloy carbon steels made in the converter with an oxygen-enriched blast, or vacuum-treated after the blow, steels containing arsenic as an alloying constituent, low-alloy steels without a thermal treatment, and austenitic steels.

This laboratory has developed a new weldability test. The specimens, which consist of small bars, 2 x 5 x 100 mm, are heated by a resistance welding transformer to simulate the thermal effects of welding, and given different quenching treatments. The resulting structures are then examined under the microscope. With this method, tests up to 1300° C are being made.

They also use a high-temperature tensile tester with a very short testing cycle of 0.018 sec. It is operated by magnets and is used with temperatures from 20 to 1300° C on small samples which have a reduced cross section of 2 x 3 mm, and which are brought to the desired temperature by induction heating.

Another project deals with the relationships between bead dimensions and thermal effect.

Professor Rykalin is widely known for his work on problems of heat flow. The investigations aimed at establishing the laws governing the heat flow in arc welding have been concluded, those relating to resistance welding are nearly completed, while future work on gas welding is still in the planning stage.

The effect of magnetic fields on the formation of the arc is the subject of another research project.

Nearly all types of welding equipment manufactured in the USSR, are available, and the laboratory has a shop of its own for equipment development work.

II. "Paton" Institute for Arc Welding of the Academy of Science at Kiev

This institute was founded in 1929 as a small laboratory for making comparative investigations of riveting and welding and for the mechanization of manual welding. In 1934, it was elevated by governmental decree to a scientific institution of the Academy of Science of the USSR, and became a center of welding research. The institute has been doing work on problems of welded construction, welding engineering, mechanization of manual welding and automatic welding.

It seems that the early program of "mechanization of manual welding" ran into some difficulties with the so-called Stakhanov movement and was relegated to the background. In the years prior to the war a great deal of work was done in the research and development of submerged-arc welding, including equipment, fluxes and welding wires and by 1941 this process was in large-scale use in about 20 industrial plants. During the war the institute had to be moved farther into the interior of the country and was re-established at Kiev in 1944, and practically all the efforts were now concentrated on submerged-arc welding, including the pertinent problems of construction, metallurgy and equipment development.

Today, the institute has a staff of 400, half of whom are scientists and engineers. The institute comprises 10 departments:

Metallurgy. Its main task is the development of all types of submerged-arc welding fluxes for low- and high-alloy steels, for overlays, for nonferrous metals, etc.

New Welding Processes. This laboratory has been credited with the development of the novel electric-slag welding process, and with vertical submerged welding, particularly of butt joints in the field erection of bridges. The department also is busy on problems connected with the welding of stainless steels.

Electrical Engineering. This department does research on the welding arc, particularly on the submerged arc, and also on resistance welding problems related mainly to the flash-butt welding of pipes.

Welding Apparatus. Its work complements that of the other departments and is concerned with the development of the necessary equipment and appara-

Rudolph O. Seitz is affiliated with the Air Reduction Laboratories, Murray Hill, N. J., as information specialist.

* Neumann, A., "Die Forschung der Schweisstechnik in der Sowjetunion," *Schweisstechnik*, 6 (7), 194–199 (1956).

Semi-Automatic Hard-Facing...

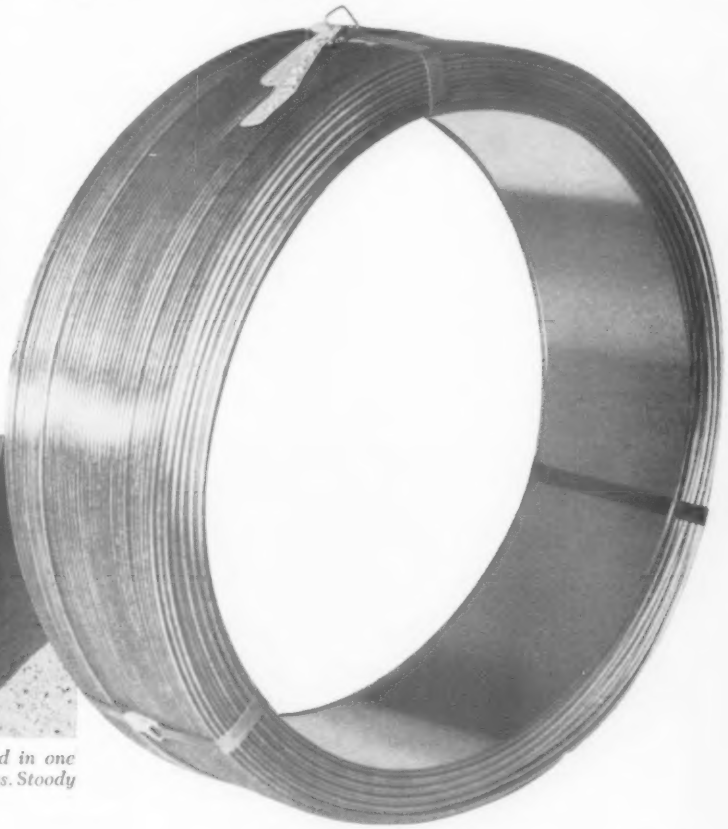
AN ADVANCE IN THE WELDING FIELD

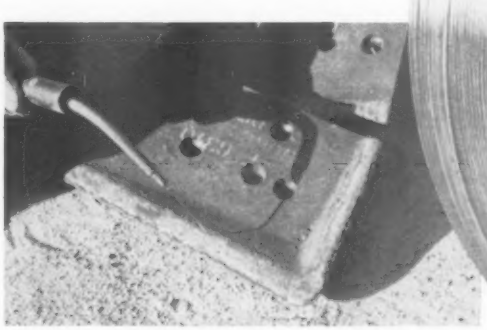
pioneered by STOODY COMPANY

One of the new developments in welding is the series of fabricated tubular alloy wires for application through the semi-automatic welder. Stoody Company pioneered this new process as a means of attaining higher deposition rates and reducing costs. Wire feed is entirely automatic; a motor-driven roll feeds the continuous wire as the arc is struck, continuing until the arc is broken. The operator has only to guide the feed nozzle.

First to supply these alloy wires to the welding industry, Stoody Company now produces the widest available selection of alloys including one containing Borium (tungsten carbides). The range covers alloys for most wear problems involving abrasion and impact. Deposits of these wires closely parallel analyses of similar manual and fully automatic electrodes.

Typical Semi-Automatic Welder *feeding Stoody Wires for semi-automatic Hard-Facing.*





Bulldozer End Bits: *Can be hard-faced in one third of time required by manual process. Stoody 121 is recommended.*

Crusher Rolls: *An ideal application for Stoody 100 because of excellent wear resistance and impact strength. Rolls can be hard-faced much faster with semi-automatic welder.*

The advantages of semi-automatic hard-facing are numerous. Welding speed is 2 to 4 times that of the manual method; there are no stub end losses; savings in welding time and labor costs are enormous; weldor fatigue is reduced. Wires are bare and thus eliminate the need for flux and flux dams; the work is visible at all times during welding. Low penetration reduces dilution of the deposit, assures maximum wear resistance, which is usually superior to that of comparable manual deposits.

Stoody wires, relatively new in the semi-automatic field, are backed by more than 10 years of experience in the production of wires for the fully automatic welder. Your Stoody dealer will be glad to demonstrate the semi-automatic process in your own plant.

STOODY COMPANY

11927 East Slauson Avenue • Whittier, California

tus, including welding positioners, which is carried to the prototype stage.

Physics and Chemistry. This service department comprises a number of physical, chemical, X-ray and isotope laboratories. A full range of the most modern instruments is available, such as spectrographs, electron microscopes, apparatus for corrosion testing, etc. In addition to their routine tasks, this group also does research on testing methods related to welding.

Strength of Welded Structures. At present, comprehensive investigations of brittle fracture and static strength at low temperatures are carried out in this department, as well as dynamic tests related to the construction of welded bridges and machinery.

Weld Redesign. This department does work on light-weight construction, i.e., on the creation of weight-saving designs, particularly for storage tanks and railroad cars.

Technology of Welded Construction. Its task is the coordination between automatic welding and design for the purpose of facilitating the widest possible use of automatic welding. In the past, this work has been mostly for the benefit of ship building, but it now includes other industries, too.

Technical Aid. This is a group of qualified welding engineers who are available for consultation on welding problems which are beyond the capabilities of the respective plant personnel, particularly during the initial period of introducing a new automatic welding process.

Shops. The institute maintains four shops with a staff of about 100, where models and prototypes can be built in a short time. When some new equipment is considered ready for field testing, the shop will manufacture the desired number of specimens.

III. "Bauman" Institute of the Moscow Polytechnical Institute

The department of mechanical engineering of the Moscow Polytechnic Institute offers 23 special curricula, e.g., turbine construction, welding engineering, foundry engineering, etc.

The chair for welding engineering has been in existence for 25 years (Professor Nikolayev). Students of all special branches of engineering are required to attend 50 hours of lectures on welding engineering. In order to become a graduate welding engineer a student must put in $5^1/_2$ semesters after completing the general curriculum. The special welding engineering curriculum comprises the following main subjects: electric machines, welded designs, heat transfer, metallurgy, physics of the arc, resistance welding, gas welding and cutting, automatic welding, and materials and weld testing.

In addition, there are three lab courses of eight to ten weeks each. The graduate thesis usually consists of a technical paper related to a research project in the student's chosen special field. These projects are carried out in cooperation with the industry which is benefited by its results. The student must also submit two practice designs, one for a piece of welding equipment, and one for a welded structure (crane, bridge, etc.).

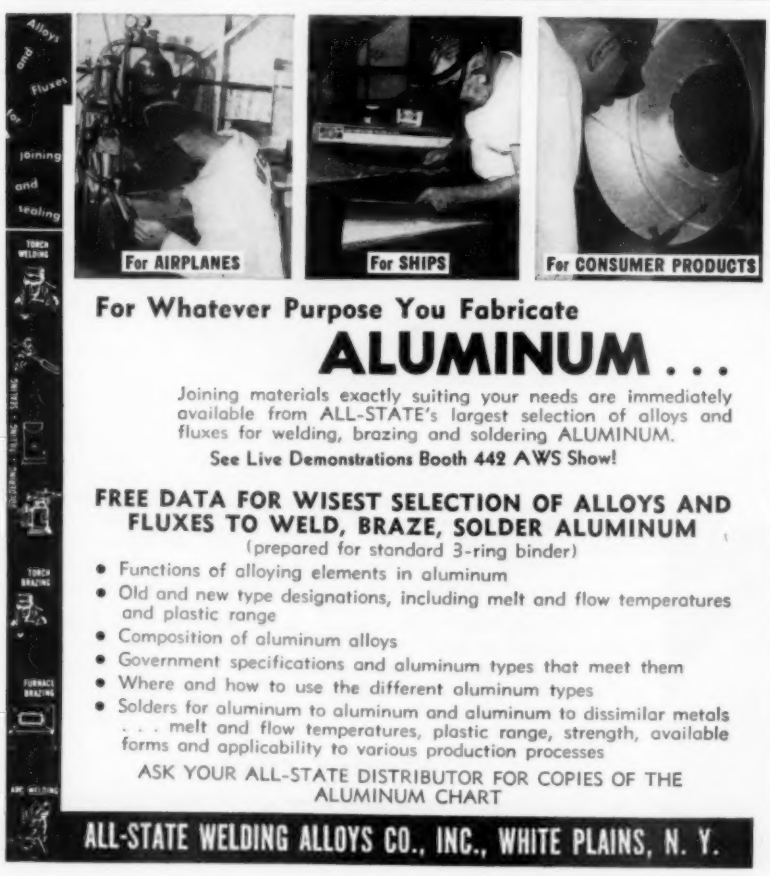
Besides teaching, the welding engineering department also takes on special research projects which are carried out in the different specialized laboratories belonging to the department. Of these special projects the following may be mentioned: investigation of internal stresses and their effect on load capacity; investigation of stress distribution in fillet welds; investigation of deformation resulting from flame cutting; investigation of weld shrinkage and proper welding sequence; investigation of fatigue strength of defective butt welds; ultrasonic testing of weldments; physical testing of metals at elevated temperatures; investigation of the plasticity of materials; investigation of fractures and cracks; investigation of weldability; powder flame cutting; and development of special automatic welding equipment.

These laboratories are equipped with all types of welding apparatus used in the USSR, such as automatic welding heads, resistance welding machines, submerged-arc welding equipment, gas welding and cutting equipment, apparatus for welding thermoplastic materials, etc. The German visitors were particularly impressed by an automatic head for the inert-gas-shielded welding of nonturnable pipe butt joints. This machine can handle pipe diameters from 60 to 200 mm and wall thicknesses of 3 to 20 mm. It rotates 360 deg, uses a 1-mm welding wire and does not require preliminary tack welds.

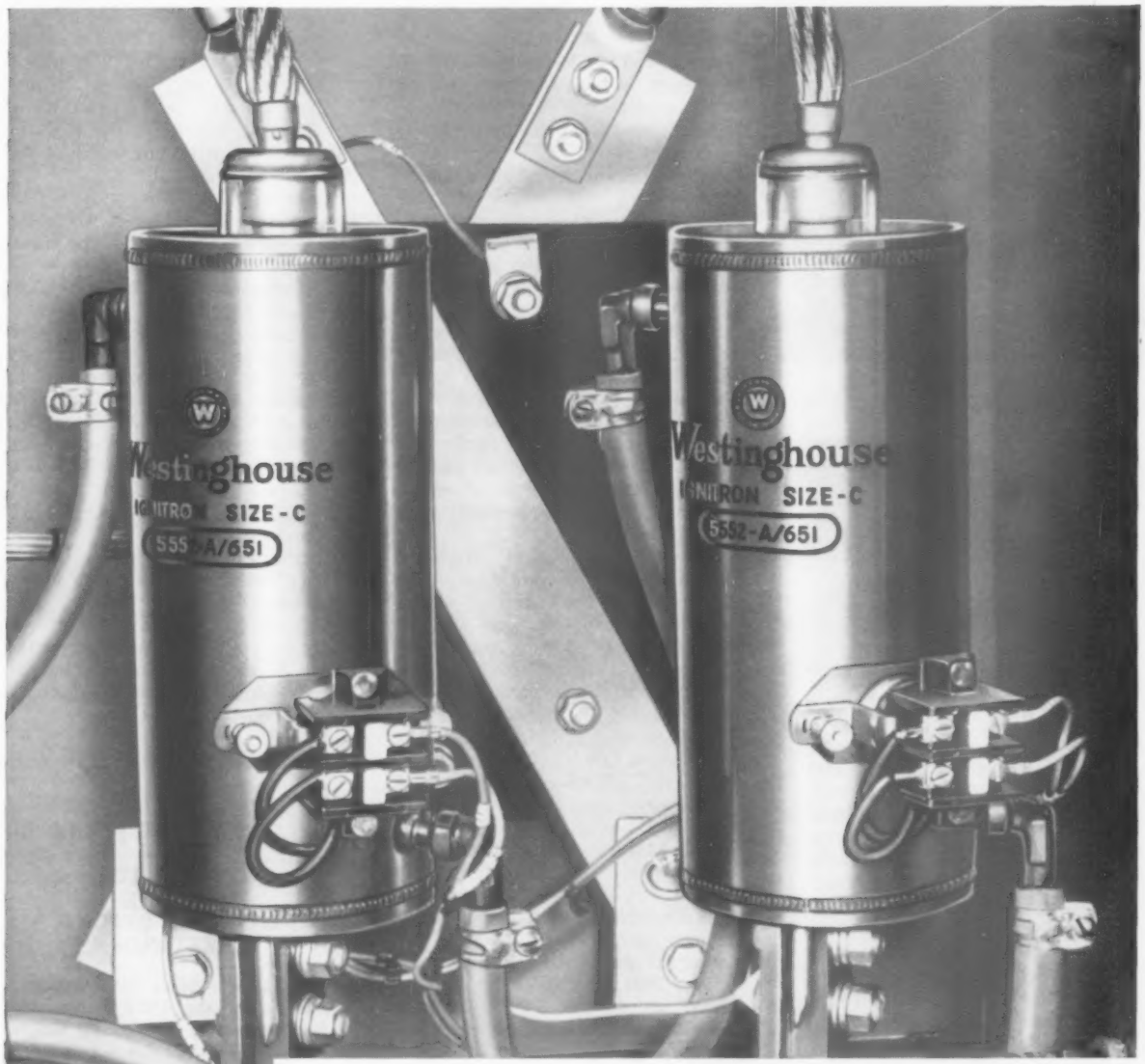
In addition to the polytechnical institutes there are more than twenty trade schools distributed throughout the country for the training of welding technicians and specialists.

IV. TsNIITMASh Institute of the Ministry for Heavy Machine Construction at Moscow

This institute was founded in 1931 and has, at present, a staff of 1000. Of these, 600 are engineers and 140 have higher degrees. The tasks of the institute comprise scientific problems related to the construction of heavy machinery, engineering problems and technical aid for the plants under the jurisdiction of the ministry. The institute has, among others, the following departments: foundry, forging, welding, de-


Alloys and Fluxes for joining and sealing
TORCH WELDING
SOLDERING - FILLING - SEALING
TORCH BRAZING
FURNACE BRAZING
ARC WELDING
For AIRPLANES
For SHIPS
For CONSUMER PRODUCTS
For Whatever Purpose You Fabricate
ALUMINUM . . .
Joining materials exactly suiting your needs are immediately available from ALL-STATE's largest selection of alloys and fluxes for welding, brazing and soldering ALUMINUM.
See Live Demonstrations Booth 442 AWS Show!
FREE DATA FOR WISEST SELECTION OF ALLOYS AND FLUXES TO WELD, BRAZE, SOLDER ALUMINUM
(prepared for standard 3-ring binder)
• Functions of alloying elements in aluminum
• Old and new type designations, including melt and flow temperatures and plastic range
• Composition of aluminum alloys
• Government specifications and aluminum types that meet them
• Where and how to use the different aluminum types
• Solders for aluminum to aluminum and aluminum to dissimilar metals . . . melt and flow temperatures, plastic range, strength, available forms and applicability to various production processes
ASK YOUR ALL-STATE DISTRIBUTOR FOR COPIES OF THE ALUMINUM CHART
ALL-STATE WELDING ALLOYS CO., INC., WHITE PLAINS, N. Y.

Westinghouse **IGNITRON TUBES** still the industry standard.



Westinghouse invented the Ignitron tube and has maintained a record of improvements that are today the accepted industry standards:

• kovar seals to permit use of steel envelopes • improved ignitors to assure accurate ignition.
• thermostatic control for overload protection and water savings.

For highest quality Industrial and Special Purpose tubes—always specify Westinghouse.

YOU CAN BE SURE...IF IT'S Westinghouse

7ET-4103-B

Danny says:

"Slag removal is a snap with Airco 78E electrodes"

I find that easy slag removal is just one of the many advantages of Airco 78E electrodes. This deep penetrating, all position electrode produces high quality weld metal which sets up rapidly. It's free from porosity, even when welding in the vertical down position. I especially recommend it for welding mild steel where high ductility and tensile strength are essential.

Why not send for the free Airco Electrode Guide which will help you select the right electrode for your specific job. Request catalog 1318.

AIRCO

AIR REDUCTION SALES COMPANY

A Division of
Air Reduction Company, Incorporated
150 East 42nd Street, New York 17, N. Y.

velopment of power presses, rolling mills and testing of structural elements.

The welding department has about 80 members. Its work is mainly concerned with developments in automatic welding, coated electrodes, particularly for high-alloy steels, arc welding and resistance welding problems.

The department is made up of the following sections:

Automatic Welding. This group has developed a new submerged welding head and carriage. Great success has been achieved in CO_2-shielded welding. At present, further development work is being done on the electric-slag welding process originated by the Paton Institute.

Electrodes. This is the most important laboratory in the Soviet Union for the development of standard and special electrodes. At present, much attention is paid to the problem of incorporating alloying constituents into the coating.

Arc Welding. Research on manual arc welding and on arc fundamentals is being pursued in this section.

Resistance Welding. Here, the efforts are directed toward the improvement of resistance welding, particularly spot welding of austenitic and pearlitic steels. Several new types of equipment and control mechanisms have been developed.

Testing of Structural Elements. Although this department is a separate unit, it does all the testing of welded structural elements entering into the construction of heavy machinery. All types of testing machines are available. Particular emphasis is laid on the effect of internal stresses, surface condition and surface deformation (peening) on fatigue strength.

The TsNIITMASh institute is strictly an industrial research and development organization operated for the benefit of the heavy machine construction industry. Therefore, the projects assigned fall under the category of applied research, and the introduction of new processes and designs into industry is one of the principal tasks. In some fields research of a more fundamental nature is also being carried on. The staff members are frequently given teaching assignments and ample opportunities exist for educational advancement. The cooperation between the staff and the industry is very close.

V. VNII-STROYNEFT Institute of the Ministry for the Petroleum Industry, Moscow

This institute is engaged in the research and development of methods of fabricating pipelines and gas and fuel storage tanks. One of its most important divisions is the welding department whose work is devoted chiefly to the application of automatic welding and of special processes in the construction of piping and storage tanks.

The group in charge of automatic welding has developed a small submerged-arc welding machine for making double fillet welds on fuel tanks up to 5000 m^3 capacity. The German visitors comment particularly on a submerged-arc welding machine for making pipe welds which permits overhead welding. How this is done is not made very clear. They merely state that "the powder is pressed against the pipe by a spiral." The root bead is welded at a rate of 37 m/hr. The second welding head operates in the normal position and the finishing bead, therefore, requires turning of the pipe (at 30 m/hr). This process is still in the development stage.

Another group is working on a pipe pressure-welding process in which the heat is supplied by a ring-type transformer. This method appears to be very economical and is said to be ready for practical application. In the materials testing section a new "magnetographic" test method has been perfected. Two coils are placed next to the weld and a magnetic tape is attached to the weld joint. Then the current is turned on for 1 sec, the tape is removed and fed into an oscillograph which shows any defects present in the weld. The tape may be demagnetized and reused about 30 times.

Another subject of study is the behavior of welded joints at low temperatures (down to −40° C) in a wind tunnel.

Since the institute is operated for the benefit of the petroleum industry, its objectives are defined by the demands of that industry.

(To be concluded in May 1957 issue)

ATTENTION

AUTHORS FOR 1958 AWS NATIONAL SPRING MEETING

Authors who plan to propose papers for the 1958 National Spring Meeting in St. Louis, Mo., are informed that the necessary abstract forms are now being processed for distribution. Complete papers, or abstracts consisting of not less than 500 words, must be submitted to AWS National Headquarters prior to August 1, 1957 if they are to receive consideration. If needed, additional copies of abstract forms may be obtained by writing to National Secretary, American Welding Society, 33 W. 39th St., New York 18, N. Y.

HOW FLASH-BUTT RESISTANCE WELDING IS USED TO FABRICATE PRESSURE VESSELS

Severe test program proves Sciaky techniques of resistance welding provide the safe welds necessary for assembling butane gas containers

In a program undertaken to determine the metallurgical advantages of flash-butt welding for joining half shells of butane gas containers, Sciaky has established the suitability—and superiority—of the process for this application. The flash-butt process offers a 100% strength factor compared to 80% for flame or arc welds.

Job Description

Figure 1 shows the half shell and the assembled container. The metal is deep drawn low carbon steel. The

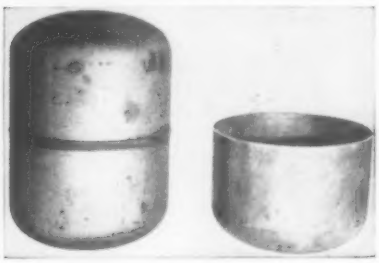


Fig. 1 At the right is a single half shell. At the left are the half shells joined by flash welding, flash not removed.

half shell has an I.D. of 11.6" and an O.D. of 11.8" or a cross section of 3.63 sq. in.

Special clamps were developed so that the clamping pressure could be applied to a maximum surface of the parts to be welded. End and side views of the clamp arrangement are shown in Figure 2.

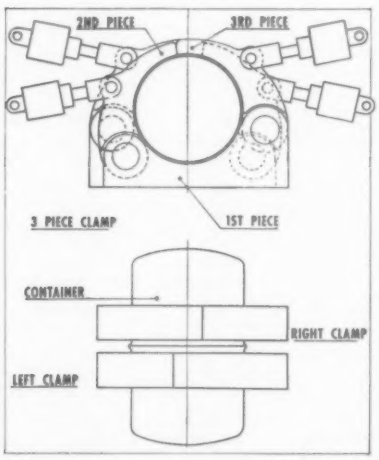


Fig. 2 Clamps for joining half shells.

The welder is a 300 KVA Sciaky Flash-Butt Welder with an upsetting force of 25,000 psi. Current is supplied to both the upper and lower clamping dies in order to assure uniform distribution throughout the diameter. One platen is fixed and the other movable. The flashing system is pneumatically operated and flashing time controlled by an adjustable metering valve.

A wedge cam provides the proper platen acceleration for flashing. A tap switch affords sixteen steps of heat regulation. Copper alloy clamping dies are used as locators and also serve as back-ups for the piece parts during the upsetting.

Test Results

The safety of the flash-butt welds was extensively tested under hydraulic pressure. Two such containers are shown in Figures 3 and 4 and for comparative purposes a fusion welded container in Figure 5.

Extensive metallurgical tests were also conducted from which the following conclusions were drawn:

1. Flash-butt welding makes it possible to obtain a strictly autogenous weld. This is true because the weld is made without the addition of extraneous material, and because the upsetting action displaces the melted base metal and impurities at the weld joint.
2. The flash-butt process makes it possible to obtain a joint having the same consistency on the inside and on the outside of the containers. See the macrographs, Figures 6 and 7.

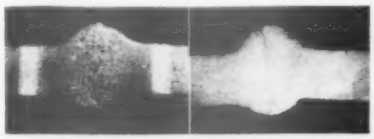


Fig. 6 Macrographs of flash welds before (left) and after annealing. Note consistency on both inside and outside.

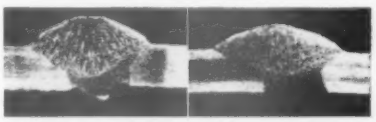


Fig. 7 Macrographs of arc welds before (left) and after annealing. Note irregularities on inside due to lack of penetration of extraneous material.

Complete Report Available

A complete, detailed report with extensive illustrations and the results of additional tests is available without charge. Please write on your company letterhead asking for the *"Engineering Report on Resistance Welding of Butane Gas Containers."* There is no obligation.

Fig. 3 Flash welded and annealed container which burst at 1349 psi. Weld elongation was 29.6%.

Fig. 4 Flash welded and annealed container which burst at 1278 psi. Weld elongation was 24.3%.

Fig. 5 Fusion welded and annealed container which burst at 994 psi. Weld elongation 11.6%.

SCIAKY® *Helps Put Profit Into Manufacturing*

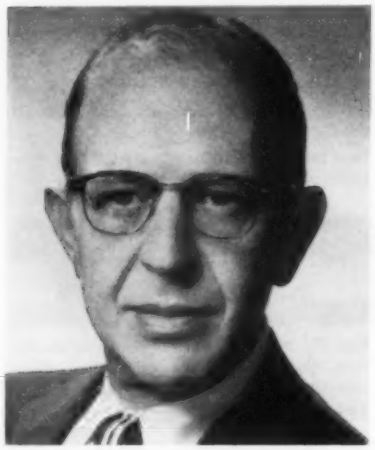
Sciaky Bros., Inc., 4919 West 67th St., Chicago 38, Ill., Portsmouth 7-5600

PERSONNEL

Gilbert Named Publishing Director

Lew Gilbert has been named publishing director of *Industry & Welding* and *Welding Illustrated*, both published by the Industrial Publishing Corp., Cleveland, according to an announcement by Irving B. Hexter, company president.

Mr. Gilbert first joined the magazines in 1949 as an associate editor.



Lew Gilbert

Since that time, he has served as editor, executive editor and general manager. He is today acknowledged as a leading authority on the welding processes, welding equipment and supplies, and is a national director of the AMERICAN WELDING SOCIETY.

Prior to joining the magazines, he was engaged in research and development of welding electrodes with Metal & Thermit Corp., New York, welding engineering at M. W. Kellogg Co., Jersey City, and technical sales for Champion Rivet Co., Cleveland.

In his new post, Mr. Gilbert will direct all phases of the magazines' activities, both editorial and sales.

Ross Named Vice-President

H. T. Ross has been named vice-president—engineering, Linde Air Products Co., a Division of Union Carbide and Carbon Corp., according to E. B. Suydam, president of this Division.

Mr. Ross joined Union Carbide in 1928 as a junior engineer at the laboratory of Linde Air Products Co. in Buffalo. He progressed through the Linde organization occupying various positions at different locations including Trafford, Pa.; Pittsburgh, Pa.; Chicago, Ill.; and New York, N. Y. He became manager of engineering for the company in 1955, which position he held at the time of his present appointment.

Mr. Ross was born in Van Wert, Ohio. He received the degree of B.S. from the University of Michigan in 1928.

Fritch Named NCG Plant Manager

Appointment of Carl F. Fritch, Jr., as factory manager of National Cylinder Gas Co.'s 19th St. plant in Cicero has been announced by Charles J. Haines, president.

Mr. Fritch will be in charge of general stores' activities as well as the production of welding and cutting torches and equipment, welding electrodes, shape-cutting machines, arc welders and medical apparatus for inhalation therapy. He had been assistant to the president of Barco Manufacturing Co., Barrington, Ill.

Mr. Fritch, 38, was graduated from Worcester Polytechnic Institute at Worcester, Mass., in 1940 and was a Navy commander during World War II.

Wallace and Pease Appointed by Airco

Effective Jan. 1, 1957, H. C. Wallace, district manager of Air Reduction's Louisville, Ky., sales office was appointed assistant regional sales manager of the Southern Region with his headquarters remaining in Louisville, Ky., it was announced recently by John J. Lincoln, Jr., regional vice-president.

H. C. Wallace

A. C. Pease

A. C. Pease, assistant sales manager, Louisville, succeeds Mr. Wallace as district manager.

Mr. Wallace has been with Air Reduction since 1929 and has held various posts at the Louisville office. He was appointed assistant sales manager in 1936 and became district manager in 1947.

Mr. Pease, with the company since 1947, originally joined Airco's Chicago district. In 1951, he moved to Kansas City as assistant sales manager and a year later to Louisville in the same capacity, the position he has held up to this time.

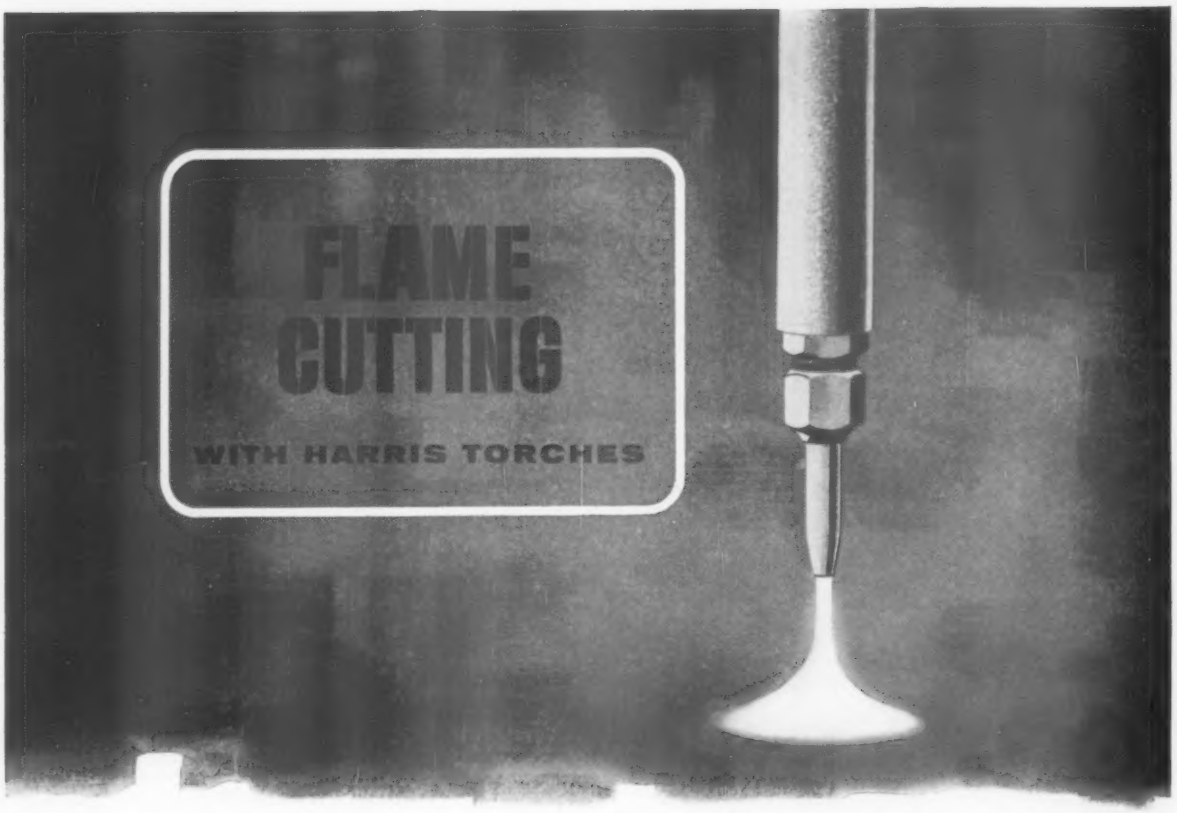
Goldsmith Honored by Professional Engineers

Lester M. Goldsmith, general manager of engineering and construction, Atlantic Refining Co., has been cited by the Pennsylvania Society of Professional Engineers in cooperation with other affiliated engineering societies, as the Philadelphia Engineer of the Year.

Presentation of the award was made by Allan H. Kidder, vice-president of the National Society of Professional Engineers, at a luncheon at the Engineers' Club, highlighting the celebration of National Engineers' Week.

Dr. Goldsmith, a graduate of Drexel Institute of Technology, who has just completed forty years of service with his company, was cited by Mr. Kidder for "his outstanding contributions to the Advancement of the Petroleum Industry, the Engineering Profession, and in the service of his country."

In an address of acceptance, Dr. Goldsmith urged young engineers of today to avail themselves of further education if they are looking toward advance-



...and natural gas saves time...money

Until recently it was thought that natural gas flame wasn't hot enough to pierce a plate of billet-thickness. A satisfactory method seemed impossible until Harris Calorific engineers developed an entirely new concept of flame cutting... A torch and tip *both* designed for use with natural gas.

The Allied Metals Company of Niles, Ohio have been using several of these torches for over a year, and they have been cutting heavy plates with natural gas, resulting in fuel savings of 80%.

Natural gas has less tendency to harden steel at the cut. This makes the blank easier to machine. Allied Metals reports that cutting time has been reduced to half that required to do the same job with other fuels. Also, natural gas piped directly to the torches eliminates the costly handling of cylinders.

Harris Calorific salesmen have the specifications for this installation, as well as information about products featured in other Harris application stories. As well-trained specialists, these men can answer *all* your questions about gas welding and cutting equipment. Call or write today!

BOOTH NO. 635
APRIL 9-10-11
Convention Hall,
Philadelphia, Pa.

AT THE 5TH AWS WINNS SHOW

HARRIS

HARRIS CALORIFIC CO.

5501 CASS AVE. • CLEVELAND 2, OHIO

Deposit up to 50% MORE WELD METAL!

Cut your welding costs with this new general purpose AC or DC Electrode. "ROCKET 24" is fast and exceptionally easy to use with "drag" technique. Produces welds that have appearance of submerged arc welding.

MAKE A TEST on your own work. You'll be surprised at the extra advantages you get.

MAIL COUPON TODAY

Hobart Brothers Co.
Troy, Ohio
Phone FE 21223

Hobart

to HOBART BROTHERS CO., Box WJ471, TROY, OHIO

☐ Send information on "ROCKET 24."
☐ I would like to try some samples.
☐ Send complete catalog on electrodes.
☐ Send catalog on Arc Welding Machines.

Name_____
Street_____
City_____ County_____ State_____

ment into the higher ranks of management.

During World War II, he served as a member of Division 12, National Defense Research Committee, Office of Scientific Research and Development, and as Expert Consultant for the War Department. He also worked with the British Ministry of War on loan from the U. S. Army Corps of Engineers.

Dr. Goldsmith is responsible for the world's first class of 30,000 dead-weight ton supertankers used in the oil industry. He is at present serving as a member of the Scientific Advisory Panel, U.S. Army Transportation Corps, Department of Defense, and also as Engineering Consultant for the Transportation Research and Development Command.

Dr. Goldsmith is a member of the AMERICAN WELDING SOCIETY.

EMPLOYMENT SERVICE BULLETIN

Positions Vacant

• Teaching position—assistant in Welding Engineering—one-half time employment. Open to any person holding a Bachelor's degree in Welding Engineering, Electrical Engineering, Metallurgical Engineering, General Engineering, Civil Engineering, Chemical Engineering or Physics, with strong interest in teaching and research. Knowledge of the welding field is desirable but not essential. It is assumed that the candidate would be interested in pursuing an advanced degree in Welding Engineering. Acceptance by The Ohio State University Graduate School is also a condition of employment. The assistant will spend approximately twenty hours a week in teaching and research activities. One quarter of course instruction will be given to aid the assistant in performing his teaching assignment.

Salary $1800 for nine months (September 15th–June 15th). Out-of-state fees will be remitted. Interested persons should forward complete résumé of educational and industrial experiences to: The Chairman, Department of Welding Engineering, Room 128, Industrial Engineering Building, The Ohio State University, Columbus 10, Ohio.

• Technical director, $12,900 annually, to coordinate and direct departments of Mechanical Engineering, Applied Physics, Metallurgy and Chemistry. Mission is to conduct applied research and development, evaluate fleet failures, and test engineering equipment and materials in the marine engineering field. Applicants should have one or more degrees in engineering and at least 3 yr of broad professional experience of a very high order. Advanced degree(s) are highly desirable. Forward inquiries or applications to the Industrial Relations Officer, U. S. Naval Engineering Experiment Station, Annapolis, Md.

Welding Manufacturing Engineer Westinghouse

BALTIMORE

excellent opening now available

Applicant should have a technical degree—E.E., M.E. Metallurgical or Chemical Engineering. Applicant should also have at least one year's background in the metal joining field and should be familiar with military specifications involving metal joining techniques and equipment.

Send a resume of your education and experience to:

Westinghouse

BALTIMORE

Dr. Jules A. Medwin, Dept. 653
Westinghouse Electric Corporation
P. O. Box 746
Baltimore 3, Maryland

Services Available

A-694. Twenty years experience in welding. Held positions as Naval inspector, technician, gang boss and combination welder. Experienced in pipe lines, storage tanks, various phases of construction, shipbuilding, repair shop, etc. Qualified for any position. Will accept employment in or out of continental United States. Can furnish the best of references. Age 38.

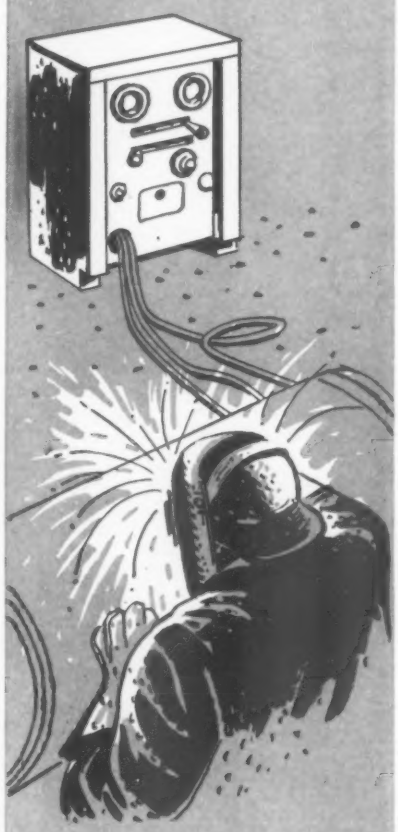
A-695. Mechanical engineer, B.S.E (M.E.). Seven years experience as welding engineer with large manufacturer includes: comprehensive knowledge of resistance spot and seam welding; cost reduction through development of new welding processes; planning, purchase and follow-up of tooling for welding; work with product engineers to design for welding. Seeks position in manufacturing or sales engineering.

A-696. Welding specialist, superintendent, research and sales, seeks position in Calumet or Midwest area. Twenty years background; all procedures and processes used today; ferrous and nonferrous metals. Can instruct and apply personally all procedures dealing with oxyacetylene, metal arc, submerged arc, inert gas, atomic hydrogen methods; also, resistance welding on low and high-carbon steels.

Welding Progress

© METAL & THERMIT CORP. 1957

at METAL & THERMIT CORPORATION • General Offices: Rahway, N. J.



NEW CONTROLLED ARC POWER SUPPLY IMPROVES WELDING

Teamed with constant speed wire feed, C.A.P.S. unit offers many advantages for semi and automatic welding.

A new constant voltage power supply recently introduced by the Metal & Thermit Corporation eliminates variables thereby lowering costs and improving weld quality. This rectifier-type machine delivers DC welding current at constant preset voltages. When teamed with a constant speed wire feed, it automatically controls the arc, maintaining a constant arc length. A built-in Arc Characteristic Controller provides a "cushion" effect, particularly desirable in low current density welding, and permits a greater range of current density with a given electrode. The result is lower costs, higher quality weldments.

C.A.P.S. welders have an efficiency of 85% or better and a power factor of 90% or higher at all settings. The equipment is rated at 100% duty cycle. Lighter and easily installed input wiring and switching are possible since less input current is required than in conventional power sources. Installation and power costs are both appreciably lower.

Literature on the M&T Controlled Arc Power Supply may be obtained by writing Metal & Thermit Corporation, Rahway, N. J.

Low hydrogen coatings improve hard surfacing electrodes

A new and different approach has been made to improve the quality and wearing characteristics of hard facing overlays. Low hydrogen coatings adapted to Metal & Thermit's HARDEX line enable these electrodes to deposit a weld metal of far less porosity and greater freedom from cracking. Penetration into the base metal and dilution by the base metal are at a minimum.

The wide line of HARDEX electrodes enables the welding engineer to select the *one* electrode which provides the best wearing quality at the least cost per pound of metal deposited. An M&T catalog, HS-56, is available through any M&T representative to simplify the selection of the right HARDEX electrode for any one of hundreds of applications.

New chrome-moly electrodes approved

For years one of the nation's foremost producers of power piping and high pressure boilers has been using a specially developed chrome-moly electrode on high pressure — high temperature service equipment. Its outstanding stress-rupture characteristics, high ductility over a wide range of temperatures, and economic advantage over other electrodes has proven the answer to safe, crack-free welds wherever high pressure—high temperature service is required.

Since these electrodes were first introduced by Metal & Thermit under the name Murex® CROLOY, more than half of the country's top petroleum refineries have approved their use for fabricating critical service equipment used in high pressure, high temperature operations. Welding engineers in other industries, too, are finding more and more use for CROLOY on other difficult-to-weld steels. A folder on M&T CROLOY electrodes and how to use them may be obtained through any Metal & Thermit representative.

WELDING SUPPLIES • RADIOGRAPHIC EQUIPMENT
PLATING MATERIALS • ORGANIC COATINGS
CERAMIC MATERIALS • TIN & TIN CHEMICALS
METALS & ALLOYS • HEAVY MELTING SCRAP

NEW PRODUCTS

Face Shields

This new "Musketeer" headrest carries a choice of four types of face shield visors which fasten to the front of a wide spark deflector, pivoted to the headband.

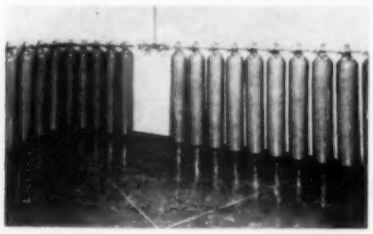
Headband and adjustable cross strap are one-piece molded nylon. Head-

band is fitted to the head by a large, winged knob and gear, also of nylon, while wearing the shield. Nylon friction pivots also adjust while the shield is in use, locking it in any position or allowing free up and down movement.

For complete details, write to Jackson Products (Air Reduction Sales Co., a division of Air Reduction Co., Inc.), Warren, Mich.

Cylinder Manifold

The Oxweld M-35, a new oxygen cylinder manifold designed to handle any unlimited number of cylinders, has been introduced by Linde Air Products Co., a Division of Union Carbide and Carbon Corp. As a basic unit, the new manifold accommodates two cylinders—one on each side of the operating con-



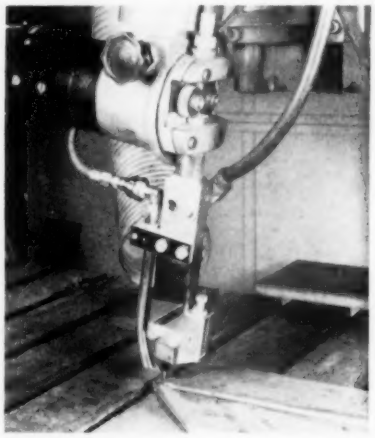
trols. Straight or curved extensions are then added in single or double rows to either bank, so that it is possible to manifold *any* number of cylinders. This makes it possible for the unit to supply any desired amount of oxygen to a piping system for welding, cutting and other industrial uses.

New Oxweld manifolds similar in operation to the M-35 are also available for water- or oil-pumped inert gases, for high-pressure fuel gases and for liquefied petroleum gases.

Addition information on the new Oxweld M-35 oxygen manifold and manifolds for other industrial gases may be obtained by writing to Linde Air Products Co., 30 E. 42nd St., New York 17, N. Y.

Dry-Type Torch

A new dry-type torch, designed for automatic gas-shielded metal-arc welding in a carbon dioxide atmosphere, has been announced by the General Electric Co.'s Welding Department, Schenectady 5, N. Y.



Interchangeable with the standard water-cooled version in its attachment to an automatic wire feeder, the new torch is rated for operation up to 800 amp. Its inverted pyramid tip design deflects spatter and reduces the possibility of spatter build up, according to company engineers.

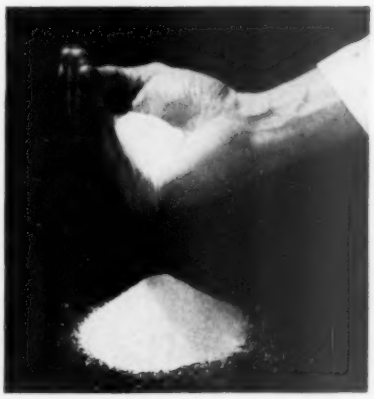
Principal feature of the torch is the elimination of hose connections which are necessary for operation of water-cooled torches.

The new torch comes equipped with tips which can handle wire from 0.045 to $\frac{1}{8}$ in., and can be used with an adapter for mounting separate from the wire feeder.

For additional details, write directly to manufacturer at above address.

Powdered Brazing Alloy

A self-fluxing brazing alloy, Handy Alumibraze, for joining many types of aluminum alloys is now being offered by Handy & Harman. This alloy, which is supplied as a dry powder and applied as an aqueous slurry, is designed for use in a molten salt bath.



It will join the following aluminum alloys: 2S, 3S, 52S, 54S, 61S, 62S, 63S, 66S and several types of casting alloys.

Handy Alumibraze alloy is said to offer a number of advantages for production brazing of aluminum, and makes possible certain joining techniques not heretofore practical.

The brazing alloy contains its own fluxing material which serves both as a flux and as a cement that keeps the alloy in place during the brazing cycle.

The Handy & Harman alloy is an aluminum-silicon eutectic (88% aluminum, 12% silicon), which carries the AWS designation BAlSi-4. It melts in the narrow range of 1070–1080° F, and is generally brazed at a temperature of 1100° F.

Further information about Handy Alumibraze alloy can be obtained from Handy & Harman, 82 Fulton St., New York 38, N. Y.

Flowmeter Regulators

A major advance in flowmeter regulators has been put on the market by the K-G Equipment Co., a division of Air Products, Inc., Allentown, Pa.

This new K-G flowmeter has been integrated into a proved regulator design and consists of an aluminum-alloy body which houses and protects a pyrex gas metering tube. According to manufacturers, this combination provides a maximum of accuracy, visibility and safety in controlling the flow of argon, helium and carbon dioxide used for shielded-arc welding and of industrial gases used in process applications.

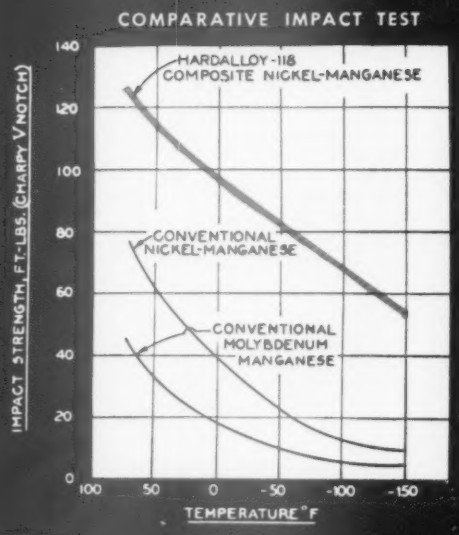
For complete information, write directly to K-G Equipment Co. at the above address.

OUTSTANDING PERFORMANCE

McKAY

HARDALLOY 118

NICKEL-MANGANESE ELECTRODE



The Nickel Manganese Weld Deposit that takes a 180° Bend!

McKay Hardalloy 118, a composite Nickel-Manganese Electrode, combines *all* the properties of nickel-manganese electrodes—and more!

- **Greater Crack Resistance**
- **Increased Toughness**
- **Higher Ductility**
- **Greater Impact Strength at any temperature**
- **Longer Service Life**

For a Nickel-Manganese Electrode that deposits an extremely tough, wear-resistant alloy that can be used for build-up and *safe* joining of austenitic manganese or manganese to mild—get the full story about McKay Hardalloy 118 Low Hydrogen Electrodes.

Send for literature on McKay Hardalloy 118

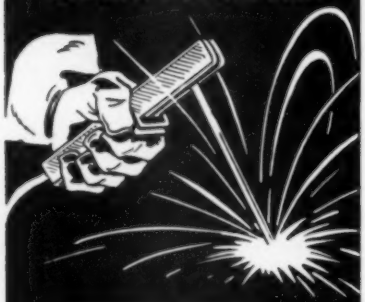
HERE IS PROOF!

Test Specimen—½" Austenitic Manganese Plate Double V Joint

Unretouched photograph of bend specimen welded with Hardalloy 118 shows a full 180° bend without fissures or cracks appearing at the weld joint or in the deposited metal.

THE McKAY COMPANY 1005 Liberty Avenue, Pittsburgh, Pa.

PLAST-IRON
GRADE B-171
POWDER
FOR
MILD STEEL, LOW HYDROGEN AND HARD-FACING
ELECTRODES



• IMPROVED QUALITY
• HIGHER DEPOSITION RATE
• FASTER OPERATION

Send for Technical Data and Working Sample

PM
PLASTIC METALS

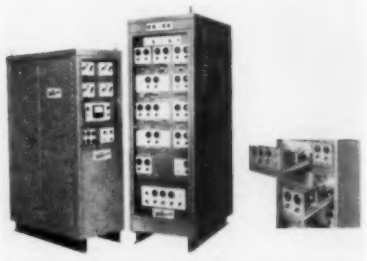
PLASTIC METALS
Division
5057 Bridge Street
JOHNSTOWN, PA.

National-U.S. Radiator Corporation

Digitronic Three-Phase Control

"Digitronic," designed and manufactured by the Weltronic Co., 19500 W. Eight Mile Road, Detroit 19, Mich., is claimed to be the most advanced three-phase frequency converter control available today. It is said to offer the welding industry an entirely new conception of resistance welding controls.

One of the outstanding features of this control is described to be its "unitized" construction. All timing, sequence and other individual functions



are designed and built as individual units. These units are built on individual chassis, of the sliding drawer type, and, all interconnections are made by means of a new type, positive lock plug. These positive contact, cam-locked plugs are cable mounted, thus permitting the control to be operated, with the units either locked in place, or rolled out. This feature greatly facilitates maintenance, because the tube operation of any unit can be readily observed. But, the basic advantage in using the plug-in units is their interchangeability. For instance, when a customer desires a seam or spot welder, plug-in units are directly interchangeable, and all accessories are identical, except the addition of the motor control, which must be in one unit, but not required in the other.

For complete details, write to manufacturer at above address.

Bronze Filler Metal

Ampco-Trode 40 is a new high-strength, ductile, easy-flowing electrode and filler rod developed for the repair and fabrication of Superston "40," a new manganese-aluminum bronze casting alloy recently announced by Ampco Metal, Inc.

According to the manufacturer, weld deposits made with the metal-arc process have mechanical properties of 95,000 psi ultimate tensile strength, 42,000 psi yield strength, 26% elongation in 2 in. and Brinell hardness of 170–190.

Ampco-Trode 40 is available as covered electrodes, bare 36-in. filler rods and spooled wire, in standard sizes for use with the metal-arc and inert-gas processes, respectively.

For additional information write to Ampco Metal, Inc., Milwaukee 46, Wis., or contact your local Ampco Distributor.

AC-DC Welders

The Lincoln Electric Co. has added two new welders to its line of Idealarc combination AC and DC welders. The new machines are 180 and 250 amp capacity Idealarc welders.

The machines are designed to operate equally well either as an AC transformer type welder or a DC rectifier type welder. A switch on the front panel changes the welder from AC operation to DC positive or DC negative. The "two-in-one" feature enables operation

of all types of manual electrodes, including stainless and alloy rods. The units are also available as straight AC machines, without DC, to which the DC rectifier can be readily added at a later date, if desired.

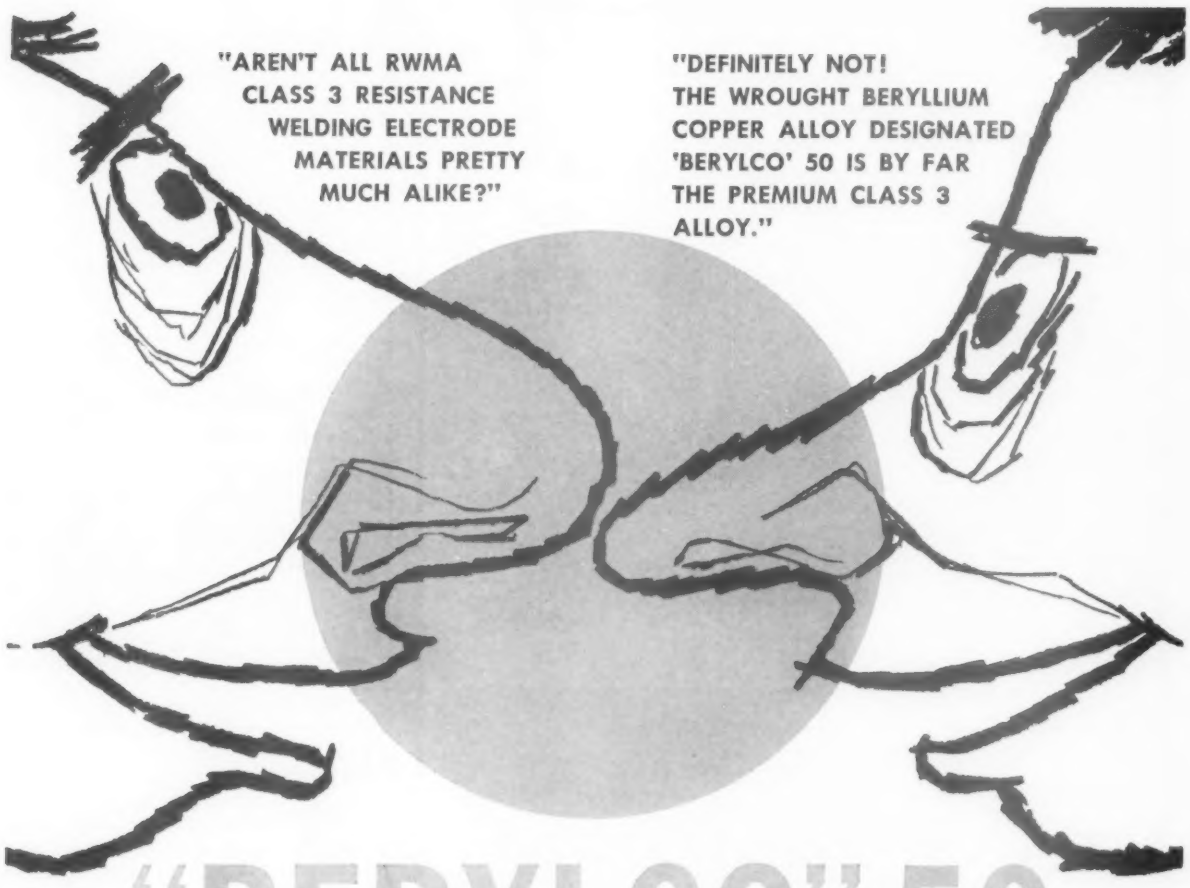
The new welders will make available, to shops having only single-phase power, the full versatility of both AC and DC welding.

Complete details may be had by writing to The Lincoln Electric Co., Cleveland 17, Ohio.

Engine-Driven Welder

Miller Electric Manufacturing Co. of Appleton, Wis., has announced the availability of their improved models AEA-200 and AEA-200-L.

Now equipped with a new and larger


"AREN'T ALL RWMA CLASS 3 RESISTANCE WELDING ELECTRODE MATERIALS PRETTY MUCH ALIKE?"
"DEFINITELY NOT! THE WROUGHT BERYLLIUM COPPER ALLOY DESIGNATED 'BERYLCO' 50 IS BY FAR THE PREMIUM CLASS 3 ALLOY."

"BERYLCO" 50

RESISTANCE WELDING ELECTRODES GIVE 3 TO 5 TIMES LONGER LIFE

Lowest contact surface resistance
Lowest operating temperature
Greatest resistance to "mushrooming"
of all the Class 3 materials

TYPICAL WROUGHT PROPERTIES			
Ultimate Tensile Strength psi 115,000	Yield Strength psi (0.2% offset) 110,000	Rockwell Hardness B97	Electrical Cond. (I.A.C.S.) 52%
Thermal Cond. 20° (CGS units) 0.53	Elongation % in 2" 11	Available Forms Rod, bar, billets, forgings	

Tips and wheels of "Berylco" 50 are available from leading resistance welding distributors

Wrought alloys catalog available upon request

BERYLCO®

THE BERYLLIUM CORPORATION, READING, PENNSYLVANIA

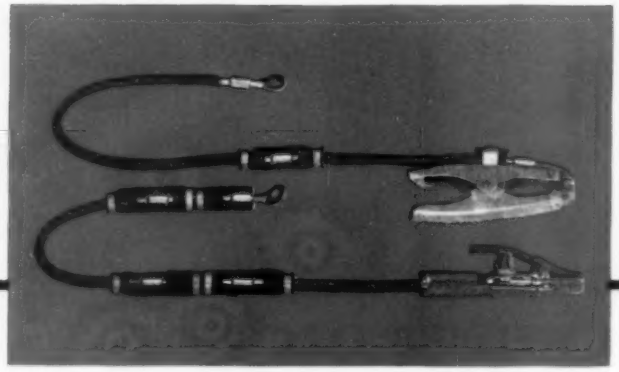
Export Department: Reading, Pennsylvania • Cable address: "BERYLCO"

Representatives in Principal Foreign Markets of the World

COOL MAN!

BOOTH NO. 605
APRIL 9-10-11
Convention Hall,
Philadelphia, Pa.

VISIT OUR BOOTH 00 AT
AWS WELDING SHOW



With CADDY holders and CADWELD connections
– that's not Jive talk – it's a fact –

TRY CADDY ELECTRODE HOLDERS today. Enjoy the coolest operating holder ever made. Eliminate the old fashioned two holder system. Lower your machine amp. settings. CADDY ELECTRODE HOLDERS are connected with CADWELD 100% efficient electrical connections.

CATALOG ON REQUEST

CADDY®

ARC WELDING ACCESSORY DIV.

Erico Products, Inc.

2070 E. 61st Place • Cleveland 3, Ohio

IN CANADA: WELDING PRODUCT SALES, Canadian General Electric Co., Ltd.
1350 Castlefield Ave., Toronto, Ontario

Onan 12.9-hp engine, the model AEA-200-L produces a full 225 amp of continuous rated, high-cycle welding current or 5 kw of 110/220 a-c power for operation of power tools, lights, milking machines, etc. One kilowatt of 110-v, d-c power is available while welding.

Twin model AEA-200 does not offer 110/220 power feature.

Both welders may be equipped with handy redi-pull starter. Optional equipment also includes rubber-tired hand running gear or road towing trailer for easy portability.

Complete specifications sent on request to manufacturer at above address.

Cayuga Index

A new motor frame and core welder made available by Cayuga Machine & Fabricating Co., Inc., is said to be giving automatic electric motor production, a real boost. The production rate is 500 units per hour. It is set up to handle 56 and 66 frames with a minimum of adjustment. Additional frame sizes can be accommodated by changing fixtures.

The new Cayuga frame and core welder takes the core on an expanding mandrel at loading station No. 1. A pushbutton is pressed to automatically expand the mandrel and clamp the core. Pushing another pushbutton brings wrapping and lining clamps into operation to wrap a prerolled frame

around the core. Immediately upon completion of the frame clamping the backing comes up into position. The table automatically indexes 90 deg to station No. 2, where with the clamps holding firm the weld is made and concurrently a hole is drilled up through the bottom of the frame into the core. At completion of the weld, the head, drill and outboard backing retract automatically and the table indexes 90 deg to Station 3. At Station 3, a chamfered pin is pressed into the frame and core hole, locking the two together. The table indexes 90 deg to Station 4, where the workpiece is ejected.

For complete details, write to Cayuga Machine and Fabricating Co., Inc., 570 Cayuga Creek Road, Buffalo 6, N. Y.

The BEST PROTECTION means MORE PRODUCTION

. . . experience proves that for comfort and protection

FIBRE-METAL *Designs Best*

1 SEAMLESS MOLDED FIBERGLAS SHELLS

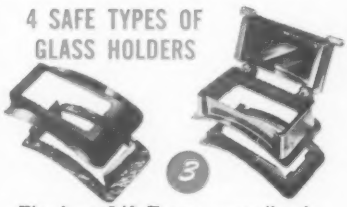
Compression-molded of Fiberglas-reinforced superior thermo-setting polyester resin, Fibre-Metal Helmets, *self-extinguishing* and with strengthening beaded edging, are the natural result of over 50 years of specialized experience. They are rugged, impervious to moisture, will not warp and are of light weight. They resist heat, abuse, and are easily cleaned and sterilized.

OVER 30 TYPES TO MEET ALL YOUR NEEDS!

COMFORT! FREE-FLOATING QUICK-ADJUST HEADGEAR 2

One size fits all head sizes! Free-floating principle . . . avoids pressure at temples and forehead. Allows comfortable shaping of headband to head! Special riveting prevents hair pulling.

4 SAFE TYPES OF GLASS HOLDERS



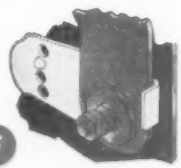
3

Fixed or Lift-Front, ruggedly designed and fabricated in Bakelite or Insulated Dowmetal. Light, durable. Metal holders are safe, insulated. Glasses easily inserted or removed.

CONVENIENCE! WIDE RANGE QUICK RATCHET HEADSIZE ADJUSTMENT 4

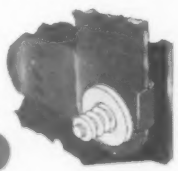
Revolutionary, light, durable material with entire mechanism enclosed in fibre tube insulating it from head of wearer. Right or left turning to adjust size . . . remains positive.

4-POSITION ADJUSTABLE HELMET STOP 5



Positions helmet for overhead and vertical welding. Positive stop, easily adjustable to any of 4 positions without tools. Allows normal raising of helmet on friction joints.

LONG-LASTING FRICTION JOINTS 6



A variety of designs for all purposes, allowing easy, outside adjustment with no plastic parts to break. A slight nod brings Helmet to operating position.

REPLACEABLE SWEATBANDS 7

The supreme comfort of Genuine Leather (also in Simulated Leather). Smooth overlap construction, no annoying wrinkles, felt padded.

CHIN REST 8 A real comfort feature always . . . and particularly for overhead welding!

Write for Catalog 24 and Bulletin 39 . . . cataloguing the best in working protection!

THE WORLD'S LARGEST MANUFACTURER OF SUPERIOR PROTECTIVE EQUIPMENT

Sold Everywhere thru Leading Distributors and Dealers

The FIBRE-METAL Products Company | CHESTER PENNA.

WELDING HELMETS • SPEEDY ATTACHMENTS • SUPERGARD HATS & CAPS • INSULATED EUREKA HOLDER • FACE SHIELDS • WELD CLEANING HAMMERS • FRESHAIR SYSTEMS

VISIT US AT THE A.W.S. WELDING SHOW, PHILADELPHIA, APRIL 9–11; BOOTH 526

ABSTRACTS OF CURRENT PATENTS

prepared by Vern L. Oldham

Printed Copies of patents may be obtained for 25c from the Commissioner of Patents, Washington, D. C.

2,773,971—"Chains and the Like"—James Teerlink, Chicago, Ill., assignor to Chains, Inc., Dolton, Ill., a corporation of Illinois.

Terrlink's patent relates to a special welding method for making a length of roller chain. The chain includes transversely extending pins for holding the sections of the chain together. The method includes several specialized steps one of which relates to subjecting the pin ends to pressure by electrodes and having current flow through the pin ends to soften them by contact resistance and compress the ends towards each other to provide enlarged heads for retaining the pins in engagement with the rotor chain means.

2,774,136—"Torch Welding"—William H. Schechter, Zelienople, Pa., assignor by mesne assignments, to Callery Chemical Co., Pittsburgh, Pa., a corporation of Pennsylvania.

This new torch welding method includes the step of supplying flux to the flame and this is done by passing the welding gas on its way to the torch into contact with the solid product of the reaction between ammonia and a lower alkyl borate.

2,774,589—"Cutting Torch Machine Having Revolving Template Mounts"—Joseph Bonner, San Francisco, Calif.

This patent relates to a cutting machine having a plurality of movable cutting torches and a tracing element engageable with a template and controlling the movement of the cutting torches. Special means are provided for positioning the template in any of a plurality of angular positions about the center of a pivot for one of the mounting members for the template.

2,774,857—"Tube Welding"—Wallace C. Rudd, Larchmont, and Robert J. Stanton, Brooklyn, N. Y., assignors to Magnetic Heating Corp., New Rochelle, N. Y., a corporation of New York.

The present patent relates to a method for welding together the edges of a longitudinal gap in metal tubing and it comprises longitudinally advancing the tubing while subjecting it to pressure from opposite sides thereof to bring the gap edges together adjacent the welding point. These edges are heated to welding temperature by applying contacts connected to a source of radio frequency current to points on the tubing at opposite sides of the gap at a position in advance of the welding point. Also, an electrical connection is provided between opposite sides of the gap at a position shortly in advance of the welding point so that a low impedance current path is provided in the metal of the tubing along the approaching gap edges.

2,774,858—"Method of and Apparatus for Welding Lap Seams"—Richard D. Heilshorn, Chicago, Ill., assignor to Continental Can Co., Inc., New York, N. Y., a corporation of New York.

Heilshorn's patent relates to a method of welding elongated lap seams. The method comprises placing the lap seam between opposing elongated electrodes extending the full length of the seam. These electrodes are brought together against the seam to grip it tightly and the electrodes are deformable upon application of welding pressure and are sufficiently resilient as to be able to return after any pressure deformation to their normal cross section for applying follow up pressure as fusion of the seam takes place. While pressure is applied to the seam, an electric current is passed through the electrodes and the seam to provide a one shot fusing and welding of the metal in the lap seam throughout the full length thereof.

2,774,859—"Electrode"—Fred H. Johnson, Detroit, Mich., assignor, by mesne assignments, to Warren Alloy, Warren, Mich., a copartnership.

Johnson's patented welding electrode comprises an elongate body having a cylindrical end portion. A removable cap is provided for this end portion and it has a cylindrical section for slidable telescopic engagement with the end of the elongate body and a specialized connection relationship exists between the elongate body aud cap.

2,775,675—Method for Welding Steel Tubing—Norbert E. Foxx, Cleveland, Ohio, assignor to Republic Steel Corp., Cleveland, Ohio, a corporation of New Jersey.

In this method of making welded pipe from a cylindrical blank, longitudinally opposed edges of the blank are moved together progressively to bring axially short portions of the edges successively into electrically conductive engagement. A flow of high frequency current is induced throughout the entire circumference of the blank and the flow of induced current is concentrated in a narrow path successively through each of the axially short engaging portions of the blank to produce high density for effective heating action. Welding pressure is applied to the blank to weld together the successively heated edges of the axially short portions of the blank referred to before.

2,775,685—Concealed Weld Stud—Dale A. Webster, Elyria, Ohio, assignor to Gregory Industries, Inc., Detroit, Mich., a corporation of Michigan.

This patent is on a special type of a weld stud in which a body having a circumferential wall and a pin terminating beyond the wall in a weld end is provided. The wall and the pin are spaced apart to provide a ferrule receiving recess about the pin, while a ferrule is present in the combination about the weld end and is positioned in the said recess.

2,775,809—Brazing of Molybdenum and Tungsten and Brazed Structures Produced Thereby—Robert Steinitz, New York, N. Y., assignor, by mesne assignments, to Borolite Corp., Pittsburgh, Pa., a corporation of Delaware.

This brazing process relates to metal selected from the class consisting of molybdenum and tungsten for brazing such metals to metals selected from the class consisting of molybdenum, tungsten and tantalum. The process includes the steps of applying to the areas of the metal parts to be united by brazing, a powder of molybdenum boride and holding the parts together and heating the contact areas to be united. This heating action raises the powder to a temperature of between 1900 and 2100° C and the heating is conducted in the absence of an oxidizing medium so that the powder melts and wets the heated metal parts.

2,776,208—Welding Rods and the High Performance Hard-Facing Alloys Produced Thereby—Howard S. Avery, Mahwah, N. J., and Charles E. Ridenour, Chicago Heights, Ill., assignors to American Brake Shoe Co., New York, N. Y., a corporation of Delaware.

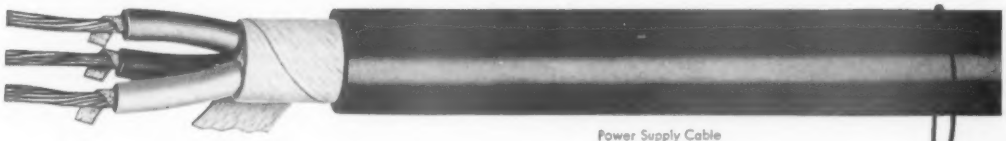
This patent is on a ferrous hard-facing alloy of chromium, which is made into a weld rod. The chromium alloy contains specified percentages of molybdenum, tungsten and other materials and primarily comprises iron.

2,776,360—Apparatus for Forming Flexible Metal Tubing—Karl H. Evert, Bartlett, Ill.

Evert's patent relates to apparatus for forming flexible tubing and it includes a mandrel about which a profiled strip of thin flexible metal may be spirally wound, and a pair of rollers oppositely disposed at the sides of the mandrel. A welding roller is positioned externally of the tube, and the welding roller is eccentrically positioned on the mandrel internally of the tube in cooperation with the first-mentioned welding roller. Electrical connections are provided so that an electric welding circuit is established through the welding roller and the eccentrically mounted roller for welding action.

Power Supply Cord

If it's worth engineers' time...



Power Supply Cable

...it's worth engineered cable

Belden
WIREMAKER FOR INDUSTRY
SINCE 1902
CHICAGO

5-W

Magnet Wire • Lead and Fixture Wire • Power Supply Cords, Cord Sets and Portable Cord • Aircraft Wires
Welding Cable • Electrical Household Cords • Electronic Wires • Automotive Wire and Cable

NEW LITERATURE

New AWS Specification for Brazing Filler Metal

An improved edition of the *Specification for Brazing Filler Metal* has just been issued jointly by the AMERICAN WELDING SOCIETY and the American Society for Testing Materials.

The 29 classifications included in this edition (AWS A5.8; ASTM B260) cover every type of brazing filler metal in common use today. They are grouped, according to principal constituents, into seven types: (1) aluminum-silicon, (2) copper-phosphorus, (3) silver, (4) copper-gold, (5) copper and copper-zinc, (6) magnesium and (7) heat-resisting materials.

The new revision provides details on chemical compositions of the filler metals, standard sizes and lengths, packaging and marking.

A handy Appendix, intended as a guide in the selection of the best filler metal for a given application, contains data on the use of each classification. This includes brazing temperature ranges, joint designs, joint clearances, color of the brazed joint and information on many other properties.

Copies of this Specification can be obtained at 40 cents each from the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y., or the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

Electrode Data Book

A new 24-page *Electrode Data Book* has been prepared by National Cylinder Gas Co. Included in the data presented in easy-to-use form are: information on AWS-ASTM arc-welding electrode specifications; how to estimate electrode consumption, summary of welding symbols, factors in selecting electrodes and other data of interest to users of arc welding. Copies of the new book (NH-504) are available from National Cylinder Gas Co., 840 N. Michigan Ave., Chicago 11, Ill.

Resistance Welding

Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., announce the availability of Vol. 5, No. 1, *Resistance Welding at Work*. This 16-page issue is taken from data of over three years of welding research and actual production welding experienced by Massey-Harris-Ferguson, Ltd., Toronto, Canada, a leading manufacturer of farm implements.

In essence this report discloses how expensive castings, forgings and arc-welded parts were replaced with resistance welded assemblies of standard sheet or bar stock, and screw machine products. The basic resistance weld types are shown in detail with actual before and after price comparisons.

For your free copy of resistance welding farm implements, write to the Chicago Plant for Vol. 5, No. 1, Department L-15.

Welding Chart

A wall chart (EW-198) on how to get better arc welding is being mailed free on request to Hobart Bros. Co., Troy, Ohio. This chart lists and gives instructions on the use of electrodes including carbon and low-alloy steel, iron powder, hardfacing and buildup, cast iron, nonferrous and stainless steel. The chart also reminds the welder of the four essentials of proper welding procedure, and shows types of joints, typical welding positions, standard steel shapes and causes of common welding troubles and what to do about them.

Regulator Catalog

Oxweld industrial gas regulators are described and illustrated in a 20-page catalog just printed by Linde Air Products Co., a Division of Union Carbide and Carbon Corp. This comprehensive catalog includes complete specifications and ordering information for 47 Oxweld regulators that are available for use with all industrial gases.

In addition to covering single- and two-stage regulators for station and manifold service, the catalog also describes a new line of CO_2 regulators and regulator manifolds for use in late model premix beverage dispensing machines. Recommended uses and installations are included in the description of each regulator.

To obtain the catalog write to Linde Air Products Co., 30 E. 42nd St., New York 17, N. Y. Ask for Form 4490, Oxweld Catalog Section 2.

Synchronous Control

Bulletin GEA-5945A, eight pages, discusses all facets of this General Electric control equipment, lists typical areas of application, explains benefits of synchronous precision control for resistance welding, describes components and accessories of the control, and discusses use of this control in spot welding, seam welding, combination welding and bench welding.

For your copy, write to General Electric Co., Schenectady 5, N. Y.

Brazing Stainless Steels

A new four-page, $8^1/_2$ x 11, two-color catalog (SD-24), entitled "Experimental and Production Brazing and Processing of Stainless Steel," is now available from Stainless Processing Division, Wall Colmonoy Corp., 19345 John R, Detroit 3, Mich. The new catalog describes and illustrates the special facilities and skills available to the user of parts fabricated of stainless steel, titanium and special alloys.

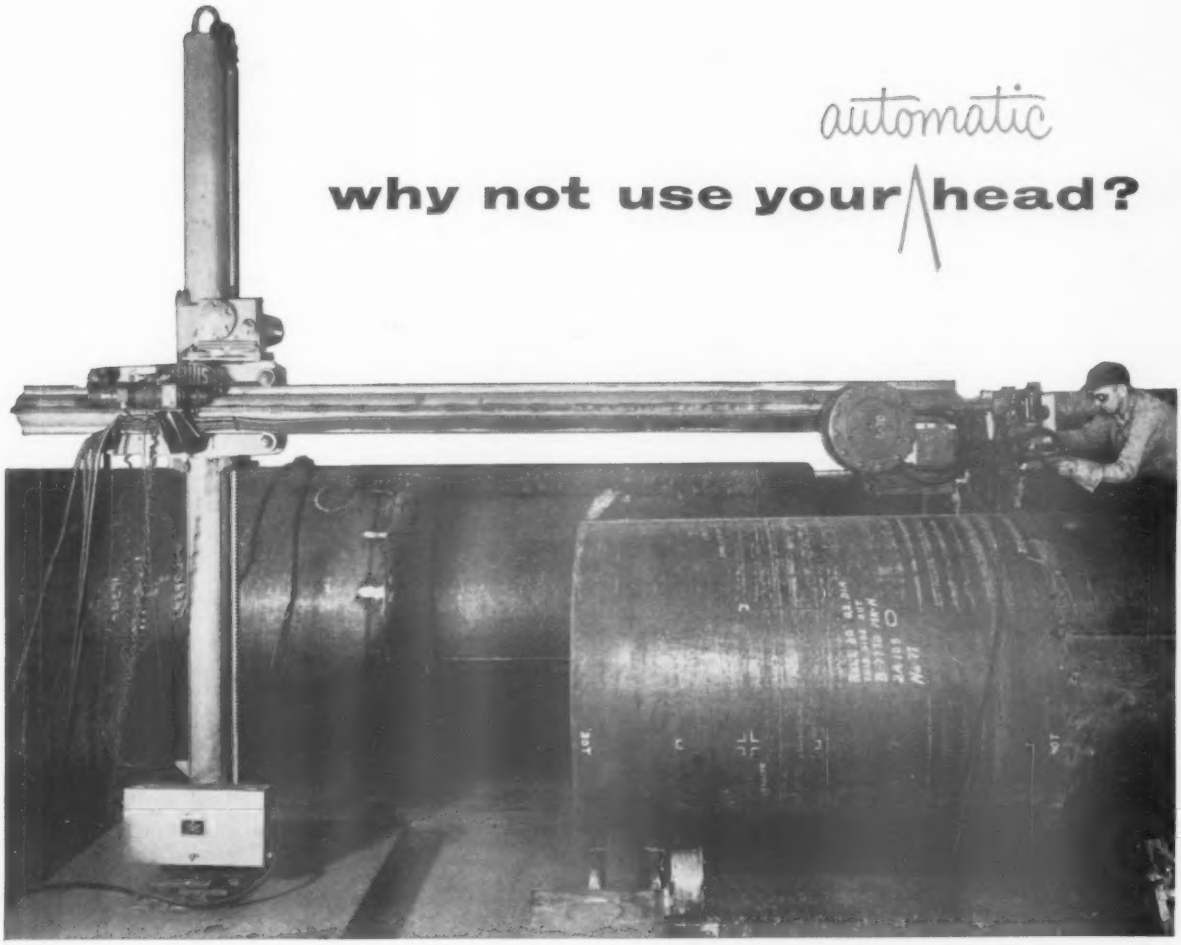
Included in the new catalog are photographs showing a cross-section sampling of the equipment and machinery in use at Stainless Processing. Other photos show typical parts that have been successfully fabricated for aircraft, automotive and other industries.

Flash-Butt Welding

Sciaky Bros., Inc., 4915 W. 67th St., Chicago 38, Ill., announce the availability of an engineering report, "Resistance Welding of Butane Gas Containers." This report is divided into two parts: Part 1—Flash-Butt Resistance Welding, and Part 2—Metallurgy.

The container body is constructed into two identical half shells of deep drawn low-carbon steel. The half shells are joined together at the open circumferential edges. Approximate measurements of the assembled tank are 1 ft in diameter and 2 ft in over-all length.

One section of the report, devoted to destruction testing, describes the introduction of hydrostatic pressures through a projection welded fitting at tank end.

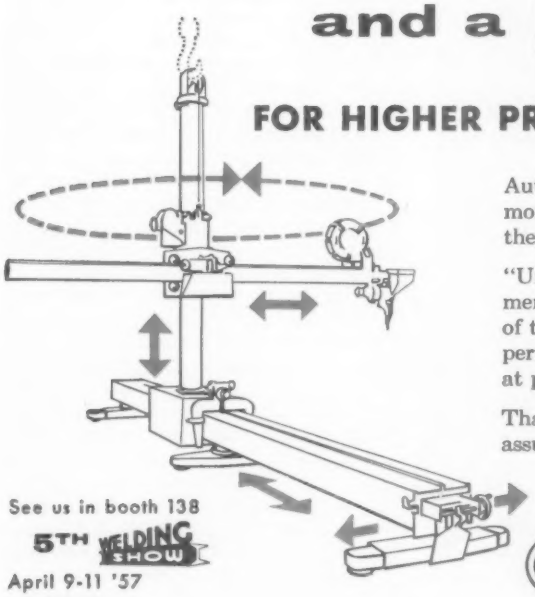


automatic

why not use your head?

and a LEWIS "UNIVERSAL"

FOR HIGHER PROFITS WITH AUTOMATIC WELDING



Automatic welding cuts costs because it is faster, more accurate, more dependable. But . . . the real key to greater savings lies in the automatic welding head manipulator.

"Universal" manipulators, designed and manufactured by a weldment fabricator, are the only *fully portable and adjustable* machines of their type. They can be set-up quickly wherever crane facilities permit . . . position any automatic head rapidly . . . pilot heads at proper welding speeds . . . operate with machine tool accuracy.

That's why LEWIS "Universals", track or pedestal types, assure greater cost savings and profits in automatic welding jobs.

For Details and Prices, write for Bulletin 6960.

See us in booth 138
5TH WELDING SHOW
April 9-11 '57
PHILADELPHIA

7495-LWE

LEWIS

THE LEWIS WELDING & ENGINEERING CORP.
WELDING DIVISION
78 INTERSTATE STREET • BEDFORD, OHIO

SPECIALISTS IN WELDMENT FABRICATION AND PRECISION WELDING EQUIPMENT

No tank samples ruptured in any resistance weld area.

For your free 24-page copy of "Resistance Welding Butane Gas Containers," write to the Chicago Plant, c/o Department L-16.

Metallizing Powder

A new two-page 8½ x 11 illustrated two-color Engineering Data Sheet (No. 53) discussing the use of the new Colmonoy C-250 (patent applied for) metallizing powder for producing crankshaft bearing surfaces is now available from Wall Colmonoy Corp., 19345 John R. St., Detroit 3, Mich.

The new data sheet discusses the properties and characteristics of the new C-250 powder and illustrates the essential steps in crankshaft preparation and application of the material. Also included is a detailed 11-step application procedure recommended by Wall Colmonoy.

Shape-Cutting Machine

The advantages and applications of Airco's No. 4 Monograph portable shape-cutting machine are described in a new 8-page catalog, now available.

Features of the Monograph are fully described in this illustrated booklet. Cutting range, weights, dimensions and other specifications are also shown.

Request a copy by writing to Air Reduction Sales Co., a division of Air Reduction Co., Inc., 150 E. 42nd St., New York 17, N. Y. Specify form ADC 660B in your request.

Welding Flux Crushers

American's new bulletin, *Better Testing and Small Scale Reduction*, describes crushers used by manufacturers to reclaim fused welding flux for reuse.

Capacities of the crushers described range from 600 to 2000 lb per hour, depending on the material and degree of fineness required. Typical installations are illustrated.

Aronson
Offers You Over 200 PROVEN Standard Stock Models of Quality POSITIONERS
"POSITIONEERED" to your exact Requirements
Patented
Aronson TracTred (T. M. Reg.) Turning Rolls for thin-walled heavy cylindrical work to 27 tons capacity. Zero to 100 IPM turning speed and Built-In Grounding.
Heavy Duty Precision Built Rubber and Steel Tired Turning Rolls, 100% overload protected. Capacities to 250 Tons. Also Tilting Rolls, Pipe Rolls and Rail Cars.
Heavy Duty Gear Driven Positioners, with Magnetic Braking, Mercury Grounding, and Optional Speeds. Capacities to 24,000 lbs.
Fully Automatic Gear Driven Positioners, featuring Power Elevation, Tilting and Rotation. 5,000 lbs. Capacity.
Heavy Duty Floor Turntables with precision speed control and Magnetic Braking, used for welding, burning, X-raying, etc. Capacities to 75,000 lbs., various heights and speeds.
Model D Gear Driven Positioners, Compact, Precise, Rugged. Capacities to 1000 lbs.
Bench Turntable Automatic Positioners with Mercury Grounding Capacities to 500 lbs.
Patented
Aronson-Twinner Permanent Magnetic Clamps, six models with thousands of uses in welding set-up work. Write for bulletin.
Aronson Universal Balance Positioners (T. M. Reg.) position your weldments effectively, instantly for downhand welding. Capacities to 2000 lbs.
Rugged Head and Tail Stock for positioning bulky weldments between centers. Table Backup for Zero Deflection, Magnetic Braking. Capacities to 160,000 lbs.
Write for detailed engineering data
Quality POSITIONERS by Aronson MACHINE COMPANY
ARCADE, NEW YORK

REVIEWS
OF NEW BOOKS

Chemical Analysis of Metals

ASTM Methods for Chemical Analysis of Metals, 1956 Edition. Price $8.00. 640 pages, 6 by 9 in. Cloth cover, Published by American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

The 1956 edition of the book of *ASTM Methods for Chemical Analysis of Metals* is the first complete revision of the volume since 1950. This publication is essentially a part of the *Book of ASTM Standards* and contains all ASTM, methods for chemical analysis of ferrous and nonferrous metals and alloys, including spectrochemical procedures. It complements Part 1 on "Ferrous Metals" and Part 2 on "Non-Ferrous Metals" of the *Book of Standards*.

There are ten completely new methods and recommended procedures in the book. These include chemical analyses for electronic nickel and titanium and two important recommended practices in the field of spectrochemical analysis. In addition, ten standards have been substantially revised since 1950. The book contains 42 methods of analysis including four spectrochemical procedures. There are five recommended practices and one specification. Some of the standards contain comprehensive diagrams of apparatus and pertinent charts.

The standards included in this book were formulated by Committee E-3 on Chemical Analysis of Metals and Committee E-2 on Emission Spectroscopy. The methods are intended for referee purposes in marketing and purchasing of metals and alloys according to specifications. They are planned to provide competent chemists with satisfactory means for judging adherence of materials to specifications.

This book is cloth bound to match the seven parts of the *Book of Standards*.

Available without charge, the bulletin may be obtained by writing the American Pulverizer Co., 1249 Macklind Ave., St. Louis 10, Mo. Ask for Bulletin 157.

Tube Joint Preparation

The Wallace Supplies Manufacturing Co., 1304 Diversey Parkway, Chicago 14, Ill. announce the availability of their new Pedi Tube Notcher for notching

tube or pipe to make fit-up joints for welding.

A 24-page, $8^1/_2$ x 11, hard-covered book shows in large clear illustrations how these jobs can be done. Two pieces of tube which have been notched are also enclosed with the book.

This information may be had free of charge by writing on your firm's letterhead.

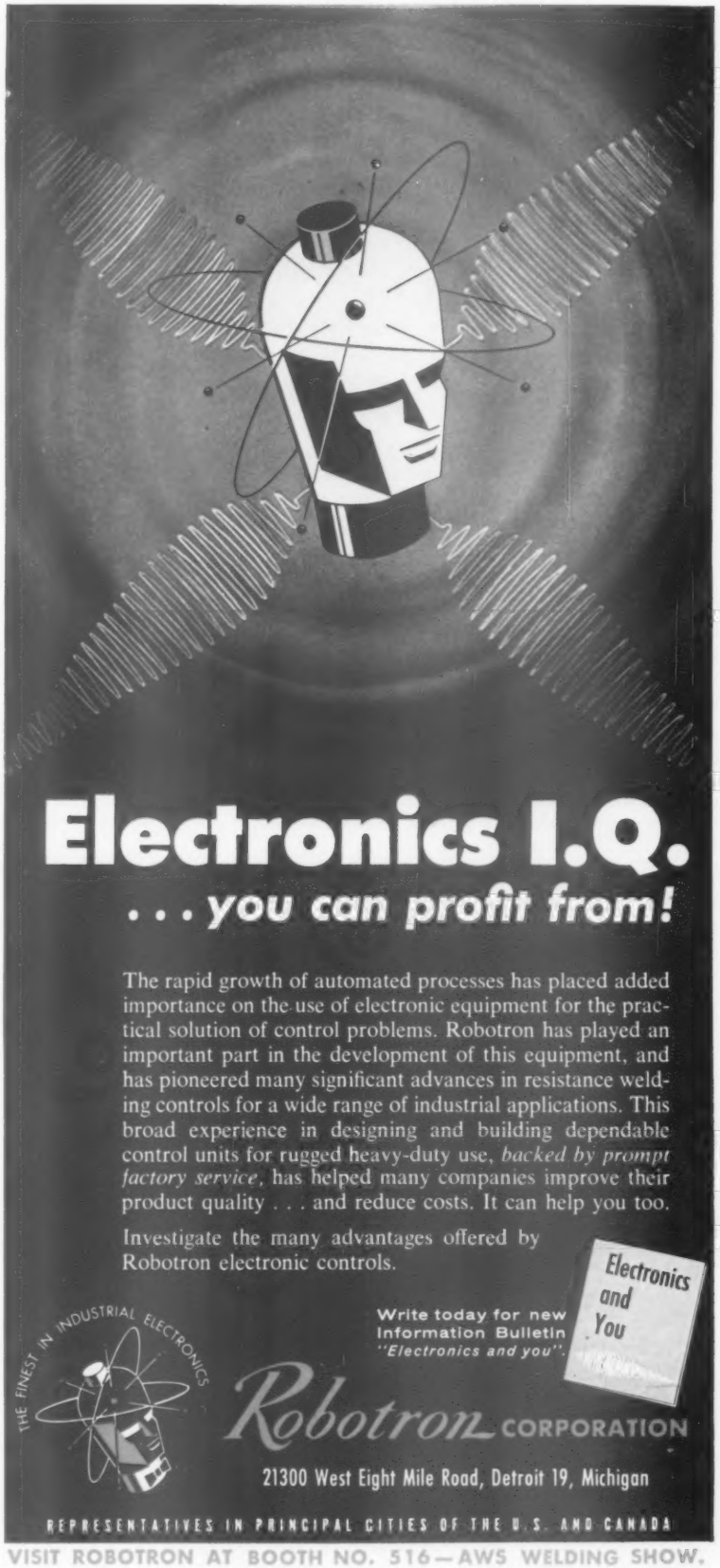
Inert-Gas Cutting

Development and applications of Aircomatic Cutting, a new method for straight line and shape cutting of nonferrous metals, are described in detail in a new 24-page informational pamphlet and catalog released by the Air Reduction Sales Co. a division of Air Reduction Co., Inc.

The new method, which employs standard Aircomatic® welding equipment for manual and machine cutting, is particularly applicable for high-speed cutting and shaping of plates and parts to be joined by gas-shielded arc welding. The cut edges produced usually require no further processing prior to welding.

While the majority of applications of the cutting process to date have involved aluminum and stainless steel, success has also been achieved with chrome steels, nickel, Monel, Inconel, copper, brass and aluminum bronze. Severance cuts have also been made in titanium and magnesium.

Copies of the new piece of literature containing information on the process can be obtained by writing to Air Reduction Sales Co., 150 E. 42nd St., New York 17, N.Y. Request Form ADE 880.


Electronics I.Q.
. . . you can profit from!
The rapid growth of automated processes has placed added importance on the use of electronic equipment for the practical solution of control problems. Robotron has played an important part in the development of this equipment, and has pioneered many significant advances in resistance welding controls for a wide range of industrial applications. This broad experience in designing and building dependable control units for rugged heavy-duty use, backed by prompt factory service, has helped many companies improve their product quality . . . and reduce costs. It can help you too.
Investigate the many advantages offered by Robotron electronic controls.
Write today for new Information Bulletin "Electronics and you".
Electronics and You
THE FINEST IN INDUSTRIAL ELECTRONICS
Robotron CORPORATION
21300 West Eight Mile Road, Detroit 19, Michigan
REPRESENTATIVES IN PRINCIPAL CITIES OF THE U.S. AND CANADA
VISIT ROBOTRON AT BOOTH NO. 516—AWS WELDING SHOW. APRIL 9-11, CONVENTION HALL, PHILADELPHIA, PA.

Tempilstik°

FOR ALL HEAT-DEPENDENT OPERATIONS

looks like a crayon... marks like a crayon... tells temperatures like a precision instrument!

Sixty-three different compositions enable you to determine and control working temperatures from 113° to 2000° F.

TEMPILSTIK° marks on workpiece "say when" by melting at stated temperatures — plus or minus 1%.

ALSO AVAILABLE IN LIQUID AND PELLET FORM . . . WRITE "WELDING SALES" DEPT. FOR SAMPLE TEMPIL° PELLETS . . . STATE TEMPERATURES OF INTEREST—PLEASE!

Available in these Temperatures (F.)

113	375	1000
125	388	1050
138	400	1100
150	413	1150
163	425	1200
175	438	1250
188	450	1300
200	463	1350
213	475	1400
225	488	1450
238	500	1500
250	550	1550
263	600	1600
275	650	1650
288	700	1700
300	750	1750
313	800	1800
325	850	1850
338	900	1900
350	950	1950
363		2000

Tempil° CORPORATION 132 WEST 22ND STREET, NEW YORK 11, N. Y.

INDEX TO ADVERTISERS

Acorn Iron and Supply Company 405
Air Reduction ..... 381, 430, Outside back cover
Alloy Rods Co. 393
All-State Welding Alloys Co., Inc. 428
The American Brass Company ..... Inside back cover
Anti-Borax Compound Co. 416
Arcos Corporation 422, 423
Aronson Machine Company 446
Belden Manufacturing Co. 443
Beryllium Corp. 439
Drawalloy Corporation 397
Erico Products 440
Eutectic Welding Alloys Corp. 409
Fibre-Metal Products Co. 441
General Electric 388–390
Handy & Harman 401
Harris Calorific Company 433
Haynes Stellite Company, A Division of Union Carbide and Carbon Corp. 415
Hobart Bros. Co. 339, 434
International Nickel Co. 344, 395
Kaiser Aluminum & Chemical Corp. 417
Lenco, Inc. 404
Lewis Welding & Engineering Corp. 445
The Lincoln Electric Company 383
Linde Air Products Company, A Division of Union Carbide and Carbon Corp. 342
P. R. Mallory & Co., Inc. 341
McKay Company 437
Metal & Thermit Corporation 435
Miller Electric Manufacturing Co., Inc. 346
National Carbide Company 425
National Cylinder Gas Company 406, 407
National—U. S. Radiator Corp. 438
National Welding Equipment Co. 340
Buell W. Nutt Company 416
Robotron Corporation 447
Sciaky Bros., Inc. 431
A. O. Smith Corporation 412, 413
Square D Company 399
Stoody Company 427
Stulz-Sickles Co. 425
Tempil° Corporation 448
Tube Turns, Inc. 419, 420
Union Carbide and Carbon Corporation
Haynes Stellite Company 415
Linde Air Products Company 342
United States Steel 385
Vickers Electric Div., Vickers, Inc. 403
Victor Equipment Company ..... Inside front cover
Westinghouse Electric Corp. 424, 434
Tube Division 429

Welding Research

SPONSORED BY THE WELDING RESEARCH COUNCIL
OF THE ENGINEERING FOUNDATION

W. SPRARAGEN, DIRECTOR

SUPPLEMENT TO THE WELDING JOURNAL, APRIL, 1957

STAINLESS STEEL FOR WELDED PRESSURE VESSELS

Abstract of an interpretive report for the Materials Division of the Pressure Vessel Research Committee

BY A. GRODNER

SUMMARY. The stainless steels are used in pressure-vessel construction to meet the increasingly severe demands of modern processing industries at reasonable cost. Specific advantages are: (*a*) Increased corrosion resistance; (*b*) elimination or reduction of product contamination; (*c*) higher strength, especially at elevated temperatures (austenitic type); (*d*) improved resistance to scaling; (*e*) improved toughness or impact resistance at very low temperatures (austenitic type); and (*f*) reduced maintenance costs.

Sixteen of the 35 standard wrought stainless steels and five of the 28 standard cast stainless steels are recognized by the ASME Boiler and Pressure Vessel Code. These grades have varying degrees of heat and corrosion resistance and varying combinations of mechanical properties which make them suitable for the construction of vessels which will serve under varying conditions of corrosiveness and at temperatures from close to absolute zero to above 1500° F.

Forming of all the wrought stainless steels is practical and relatively simple for shops familiar with steel construction. The austenitic types are particularly suited to welded construction.

Design criteria, including controls on fabrication, are well established. Treatments to establish maximum corrosion resistance and optimum mechanical properties have been developed and standardized.

A. Grodner is Chief Engineer, Alloy Fabricators Division of Continental Copper and Steel Industries, Inc.

The complete report is published as Bulletin No. 31 in the Bulletin Series of the Welding Research Council. This Bulletin describes properties and fabrication characteristics of wrought and cast stainless steels used for pressure vessel construction to meet requirements of processing industries.

This report is intended to present, to the designer and fabricator of pressure vessels, some information about those characteristics of the stainless steels of particular interest to him.

The Grades of Stainless Steels

The stainless steels are currently a family of thirty-five steels, related through their relatively high chromium content—11.5% minimum. In some grades the chromium content may be as high as 27.0%. The addition of such quantities of chromium to low-carbon steels causes a marked improvement in corrosion and heat resistance, starting with the lowest limit and improving even more with increasing chromium content. Addition of nickel further increases both corrosion and heat resistance and improves certain mechanical properties, especially at both extremes of the temperature scale. Addition of molybdenum and other elements further enhances corrosion resistance in some environments and also increases strength at elevated temperatures.

The chemical ranges and limits of the standard types of stainless and heat resisting steels, as defined by American Iron and Steel Institute (AISI), are shown in Table 1. Because AISI designations are in common use in this country and many of the grades have different designations in various ASME and other specifications, AISI Type Numbers will be used throughout this paper to identify alloys.

Analyses of cast alloys, as defined by Alloy Casting Institute, are given in Table 2. While limits on compositions are not identical to those for the wrought alloys, the corrosion resistance displayed by similar wrought and cast alloys should correspond quite closely, although porosity and coarse microstructure of castings can diminish their corrosion resistance. Under severe conditions the entire exposed surfaces of castings should be as smoothly finished as the surfaces of the wrought stainless steel used for comparison.

The various stainless steels have been grouped into three subfamilies based on their chemical composition and response to heat treatment.

Martensitic Types: 403, 410, 414, 416, 416Se, 420, 431, 440A, 440B and 440C

The steels in this group which are recognized in Section II of the ASME Boiler and Pressure Vessel Code are Types 410, and 416 or 416Se.

These steels are hardenable by heat treatment, and exhibit their best mechanical properties and maximum corrosion resistance when in the hardened and tempered condition.

The martensitic steels are ferromagnetic. With the exception of the free machining grades, Types 416 and 416Se, they are especially suitable for hot working, forging, upsetting and the like.

Table 1—Standard Types of Stainless and Heat-Resisting Steels, Chemical Ranges and Limits

Subject to variations for check analysis

Type No.	Chemical composition, % C	Mn, max	P, max	S, max	Si, max	Cr	Ni	Mo	Zr	Se	Ti	Cb-Ta	Ta	Al	N
301	0.15 max	2.00	0.045	0.030	1.00	16.00/18.00	6.00/8.00	..	..	..	..	..	..	..	..
302	0.15 max	2.00	0.045	0.030	1.00	17.00/19.00	8.00/10.00	..	..	..	..	..	..	..	..
302B	0.15 max	2.00	0.045	0.030	2.00/3.00	17.00/19.00	8.00/10.00	..	..	..	..	..	..	..	..
303†	0.15 max	2.00	0.20	0.15 min	1.00	17.00/19.00	8.00/10.00	0.60* max	0.60* max	..	..	..	..	..	..
303Se†	0.15 max	2.00	0.20	0.06	1.00	17.00/19.00	8.00/10.00	..	..	0.15 min	..	..	..	..	..
304†	0.08 max	2.00	0.045	0.030	1.00	18.00/20.00	8.00/12.00	..	..	..	..	..	..	..	..
304L†	0.03 max	2.00	0.045	0.030	1.00	18.00/20.00	8.00/12.00	..	..	..	..	..	..	..	..
305	0.12 max	2.00	0.045	0.030	1.00	17.00/19.00	10.00/13.00	..	..	..	..	..	..	..	..
308†	0.08 max	2.00	0.045	0.030	1.00	19.00/21.00	10.00/12.00	..	..	..	..	..	..	..	..
309†	0.20 max	2.00	0.045	0.030	1.00	22.00/24.00	12.00/15.00	..	..	..	..	..	..	..	..
309S	0.08 max	2.00	0.045	0.030	1.00	22.00/24.00	12.00/15.00	..	..	..	..	..	..	..	..
310†	0.25 max	2.00	0.045	0.030	1.50	24.00/26.00	19.00/22.00	..	..	..	..	..	..	..	..
310S	0.08 max	2.00	0.045	0.030	1.50	24.00/26.00	19.00/22.00	..	..	..	..	..	..	..	..
314	0.25 max	2.00	0.045	0.030	1.50/3.00	23.00/26.00	19.00/22.00	..	..	..	..	..	..	..	..
316†	0.08 max	2.00	0.045	0.030	1.00	16.00/18.00	10.00/14.00	2.00/3.00	..	..	..	..	..	..	..
316L†	0.03 max	2.00	0.045	0.030	1.00	16.00/18.00	10.00/14.00	2.00/3.00	..	..	..	..	..	..	..
317†	0.08 max	2.00	0.045	0.030	1.00	18.00/20.00	11.00/15.00	3.00/4.00	..	..	..	..	..	..	..
321†	0.08 max	2.00	0.045	0.030	1.00	17.00/19.00	9.00/12.00	..	..	..	5×C min	..	..	..	..
347†	0.08 max	2.00	0.045	0.030	1.00	17.00/19.00	9.00/13.00	..	..	..	..	10×C min	..	..	..
201	0.15	5.5/7.5	0.060	0.030	1.00	16.0/18.0	3.5/5.5	..	..	..	..	..	..	..	0.25
202	0.15	7.5/10.0	0.060	0.030	1.00	17.0/19.0	4.0/6.0	..	..	..	..	..	..	..	0.25
318† (316Cb)	0.08	2.50	0.045	0.030	1.00	17.00/19.00	13.00/15.00	2.00/2.75	..	..	..	10×C min	..	..	..
348	0.08 max	2.00	0.045	0.030	1.00	17.00/19.00	9.00/13.00	..	..	..	..	10×C min	0.10 max	..	..
403	0.15 max	1.00	0.040	0.030	0.50	11.50/13.00	...	..	..	..	..	..	..	..	..
405†	0.08 max	1.00	0.040	0.030	1.00	11.50/14.50	...	..	..	..	..	..	..	0.10/0.30	..
410†	0.15 max	1.00	0.040	0.030	1.00	11.50/13.50	...	..	..	..	..	..	..	..	..
414	0.15 max	1.00	0.040	0.030	1.00	11.50/13.50	1.25/2.50	..	..	..	..	..	..	..	..
416†	0.15 max	1.25	0.06	0.15 min	1.00	12.00/14.00	...	0.60* max	0.60* max	..	..	..	..	..	..
416Se†	0.15 max	1.25	0.06	0.06	1.00	12.00/14.00	...	..	..	0.15 min	..	..	..	..	..
420	Over 0.15	1.00	0.040	0.030	1.00	12.00/14.00	...	..	..	..	..	..	..	..	..
430†	0.12 max	1.00	0.040	0.030	1.00	14.00/18.00	...	..	..	..	..	..	..	..	..
430F	0.12 max	1.25	0.06	0.15 min	1.00	14.00/18.00	...	0.60* max	0.60* max	..	..	..	..	..	..
430F Se	0.12 max	1.25	0.06	0.06	1.00	14.00/18.00	...	..	..	0.15 min	..	..	..	..	..
431	0.20 max	1.00	0.040	0.030	1.00	15.00/17.00	1.25/2.50	..	..	..	..	..	..	..	..
440A	0.60/0.75	1.00	0.040	0.030	1.00	16.00/18.00	...	0.75 max	..	..	..	..	..	..	..
440B	0.75/0.95	1.00	0.040	0.030	1.00	16.00/18.00	...	0.75 max	..	..	..	..	..	..	..
440C	0.95/1.20	1.00	0.040	0.030	1.00	16.00/18.00	...	0.75 max	..	..	..	..	..	..	..
446	0.20 max	1.50	0.040	0.030	1.00	23.00/27.00	...	..	..	..	..	..	..	..	0.25 max

* At producer's option: reported only when intentionally added.

† Types recognized in ASME Boiler and Pressure Vessel Code, Section II—Material Specifications.

The lower carbon types which are recognized by the Code have the best machining characteristics of any of the stainless steels. Because these steels are air hardening, care must be exercised in cooling after welding and hot working to avoid high cooling stresses and possible cracking.

These steels are well suited for most moderately corrosive conditions, including water, weather and some chemicals, and are particularly valuable in applications requiring high strength, hardness and resistance to abrasion and either wet or dry erosion.

Type 410 is the basic steel in this group, the others being, in general, modifications developed to meet some special engineering needs. Types 416 or 416Se, the other grades recognized by the Code, are free machining modifications, suitable for bolts, etc.

Ferritic Types: 405, 430, 430F, 430FSe and 446

The steels in this group recognized in Section II of the ASME Boiler and Pressure Vessel Code are Types 405 and 430.

These steels, as a family, differ from the martensitic chromium stainless steels in that they are not hardenable by thermal treatment. The hardness of these steels can be increased by cold working, but only to a very limited degree. Because even the small increase in hardness obtainable is accompanied by a relatively large decrease in ductility these steels are only rarely used in the cold-worked condition.

Like the martensitic steels, the ferritics are ferromagnetic. Their coefficient of thermal expansion is relatively low, about one-third less than that of the austenitic stainless steels and about the same or slightly less than that of carbon steel. The ferritic steels offer good resistance to both oxidation and corrosion; the higher chromium types are often selected for high temperature applications involving intermittent heating and cooling as, because of their

Table 2—Alloy Casting Institute

Standard designations and chemical composition ranges for heat and corrosion resistant castings

Cast alloy designation	*Wrought alloy type (see note A)*	*Composition, % (balance Fe)*						
		C	*Mn, max*	*Si, max*	*P, max*	*S, max*	*Cr*	*Ni*	*Other elements*
CA-15	410	0.15 max	1.00	1.50	0.04	0.04	11.5–14	1 max	Mo 0.5 max†
CA-40	420	0.20–0.40	1.00	1.50	0.04	0.04	11.5–14	1 max	Mo 0.5 max†
CB-30	431	0.30 max	1.00	1.00	0.04	0.04	18–22	2 max	....
CC-50	446	0.50 max	1.00	1.00	0.04	0.04	26–30	4 max	....
CE-30	..	0.30 max	1.50	2.00	0.04	0.04	26–30	8–11	....
CF-8	304	0.08 max	1.50	2.00	0.04	0.04	18–21	8–11	....
CF-20	302	0.20 max	1.50	2.00	0.04	0.04	18–21	8–11	....
CF-8M	316	0.08 max	1.50	1.50	0.04	0.04	18–21	9–12	Mo 2.0–3.0
CF-12M	316	0.12 max	1.50	1.50	0.04	0.04	18–21	9–12	Mo 2.0–3.0
CF-8C	347	0.08 max	1.50	2.00	0.04	0.04	18–21	9–12	Cb 8×C min, 1.0 max or Cb-Ta 10×C min, 1.35 max
CF-16F	303	0.16 max	1.50	2.00	0.17	0.04	18–21	9–12	Mo 1.5 max, Se 0.20–0.35
CH-20	309	0.20 max	1.50	2.00	0.04	0.04	22–26	12–15	....
CK-20	310	0.20 max	1.50	2.00	0.04	0.04	23–27	19–22	....
CN-7M	..	0.07 max	1.50	*	0.04	0.04	18–22	21–31	Mo-Cu*
HA	..	0.20 max	0.35–0.65	1.00	0.04	0.04	8–10	..	Mo 0.90–1.20
HC	446	0.50 max	1.00	2.00	0.04	0.04	26–30	4 max	Mo 0.5 max†
HD	327	0.50 max	1.50	2.00	0.04	0.04	26–30	4–7	Mo 0.5 max†
HE	..	0.20–0.50	2.00	2.00	0.04	0.04	26–30	8–11	Mo 0.5 max†
HF	302B	0.20–0.40	2.00	2.00	0.04	0.04	19–23	9–12	Mo 0.5 max†
HH	309	0.20–0.50	2.00	2.00	0.04	0.04	24–28	11–14	Mo 0.5 max,† N 0.2 max
HI	..	0.20–0.50	2.00	2.00	0.04	0.04	26–30	14–18	Mo 0.5 max†
HK	310	0.20–0.60	2.00	3.00	0.04	0.04	24–28	18–22	Mo 0.5 max†
HL	..	0.20–0.60	2.00	3.00	0.04	0.04	28–32	18–22	Mo 0.5 max†
HN	..	0.20–0.50	2.00	2.00	0.04	0.04	19–23	23–27	Mo 0.5 max†
HT	330	0.35–0.75	2.00	2.50	0.04	0.04	13–17	33–37	Mo 0.5 max†
HU	..	0.35–0.75	2.00	2.50	0.04	0.04	17–21	37–41	Mo 0.5 max†
HW	..	0.35–0.75	2.00	2.50	0.04	0.04	10–14	58–62	Mo 0.5 max†
HX	..	0.35–0.75	2.00	2.50	0.04	0.04	15–19	64–68	Mo 0.5 max†

* There are several proprietary alloy compositions falling within the stated chromium and nickel ranges, and containing varying amounts of silicon, molybdenum and copper. Such alloys are available from licensed producers only.

† Molybdenum not intentionally added.

Designations with the initial letter "C" indicate alloys generally used to resist corrosive attack at temperatures less than 1200° F. Designations with the initial letter "H" indicate alloys generally used under conditions where the metal temperature is in excess of 1200° F. The second letter represents the nominal chromium-nickel type; the nickel content increasing in amount from "A" to "X." For example, "F" stands for the 19% Cr–9% Ni, "K" for the 25% Cr–20% Ni and "W" for the 12% Cr–60% Ni alloy types. Numerals following the letters indicate the *maximum* carbon content of the corrosion-resistant alloys; carbon content may also be designated in the heat resistant grades by following the letters with a numeral to indicate the *midpoint* of a ±0.10% carbon range. If special elements are included in the composition they are indicated by the addition of a letter to the symbol. Thus, "CF-8M" is an alloy for corrosion resistant service, of the molybdenum-containing 19% Cr–9% Ni type with a maximum carbon content of 0.08%.

NOTE A—Wrought alloy type numbers are listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast alloy chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

NOTE B—Most of the standard grades listed are covered for general applications by American Society for Testing Materials specifications A296–49T and A297–49T. ASTM specifications A217–49T, A351–52T, A362–52T, B190–50 and B207–50 also apply to some of the grades.

low coefficient of thermal expansion, they tend to retain, rather than throw, scale.

Since these steels possess fairly good ductility, they can be fabricated without difficulty by conventional methods of forming, bending, rolling, spinning and drawing, but it may be necessary to anneal the part at approximately 1550° F between successive forming operations. These steels can be buffed to an extremely high finish which resembles, and often can be matched with, chromium plate. The ferritic steels can be welded; however, in the case of the higher chromium types including Type 430, welds may tend to be brittle especially in heavy sections requiring multiple weld passes. Brittleness can be reduced by low-temperature stress relieving as specified in Paragraph UHA-32 of the Code (Section VIII).

Type 430 is the basic ferritic steel. It has corrosion resisting properties approaching those of Type 302, for some applications, and it has often been used as an alternate for that type in times of nickel shortages. Type 405 is a lower chromium nonhardenable stainless steel which can be used for services in which Type 410 might be suitable from a corrosion resisting standpoint but for which a nonhardening steel is required.

Austenitic Types: 301, 302, 302B, 303, 303Se, 304, 304L, 305, 308, 309, 310, 310S, 314, 316, 316L, 317, 318, 321, 347 and 348

This group contains the grades of most importance in design and fabrication of unfired pressure vessels. The steels in this group recognized in Section II of the ASME Boiler and Pressure Vessel Code are Types 303, 303Se, 304, 304L, 308, 309, 310, 316, 316L, 318 (316Cb), 321 and 347. Also recognized is a low-carbon modification of Type 317 which is not an American Iron and Steel Institute standard.

The steels in this group contain both chromium and nickel in analysis balance such that, in the annealed condition, they are nonmagnetic. Because of their relatively high alloy content, and their uniform mechanical and physical properties, these steels possess, as a group, the highest corrosion resistance of the stainless steels. For the same reasons they possess the best high-temperature strength. Under most conditions these steels also show the greatest resistance to scaling of the stainless and heat-resisting steels.

The austenitic stainless steels are inherently tough, as well as strong, and are, therefore, particularly suited to both service and fabrication requirements which demand these properties. They are particularly suited to deep drawing and other severe forming operations. In addition, and perhaps most important, the austenitic stainless steels have excellent weldability, and welded joints and the weldment as a whole are exceptionally tough and ductile.

Type 304 is the basic austenitic steel recognized by the Code. Others are variations developed to meet specific service or engineering needs. Types 303 and 303Se are the free-machining austenitic steels and are the grades frequently specified for bolting. Types 309 and 310 have higher alloy content and have the highest resistance to scaling of any of these alloys. Type 310 has a coefficient of expansion slightly lower than that of the other chromium-nickel stainless steels and will, therefore, tend to throw scale less during cyclic heatings and coolings.

The higher carbon types of austenitic stainless steels, and those in which the carbon is not stabilized by titanium, or columbium (with or without tantalum) are subject to precipitation of chromium carbides at the grain boundaries when held at temperatures of 1600 to 800° F, or when cooled slowly through this temperature range. These temperatures are reached in portions of the base metal during cooling from fusion welding. This critical temperature range must also be crossed during cooling from stress-relief treatment.

The precipitation of chromium carbides has the effect of lowering the amount of free chromium available in the alloy for corrosion resistance and will, therefore, tend to lower the corrosion resistance to some degree. The degree to which corrosion resistance is reduced depends upon the carbon content of the steel, the temperature and the time at temperature.

1. The low-carbon steels, Types 304L, 316L and low-carbon 317 afford additional resistance to the effects of intergranular corrosion due to carbide precipitation by making available less carbon for removal of chromium from solution. These grades have served admirably in structures or vessels which are welded without subsequent heat treatment and are used in service below 800° F.

2. For even more critical applications, including vessels used at temperatures within the critical range, the stabilized Types 318, 321 and 347 have been developed. The inclusion of strong carbide formers, titanium and columbium-tantalum, in these alloys results in the formation of carbides of these elements rather than of chromium, thus permitting the chromium to remain in

Table 3—Physical Properties of Certain Wrought Stainless Steels (Annealed Condition)

Type No.	Magnetic †	Modulus of elasticity In tension, 1,000,000 psi	Modulus of elasticity In torsion, 1,000,000 psi	Density, lb/cu in.	Specific electrical resistance at room temperature, microohms/cm/sq cm	Specific heat (32-212°F) Btu/lb/° F	Thermal conductivity, Btu/hr/sq ft/ft/deg F 212°F	Thermal conductivity, Btu/hr/sq ft/ft/deg F 932°F	Mean coefficient of thermal expansion per ° F 32-212 × 10^{-6}	32-600 × 10^{-6}	32-1000 × 10^{-6}	32-1200 × 10^{-6}	32-1500 × 10^{-6}	32-1800 × 10^{-6}	Melting point, °F	Hardenable by thermal treatment †
303	No*	28.0	..	0.29	72	0.12	9.4	12.4	9.6	9.9	10.2	10.4	..	..	2550-2590	No
304	No*	28.0	12.5	0.29	72	0.12	9.4	12.4	9.6	9.9	10.2	10.4	..	..	2550-2650	No
309	No†	29.0	..	0.29	78	0.12	8.0	10.8	8.3	9.3	9.6	10.0	..	11.5	2550-2650	No
310	No	29.0	..	0.29	78	0.12	8.0	10.8	8.0	9.0	9.4	9.7	..	10.6	2550-2650	No
316	No*	28.0	..	0.29	74	0.12	9.4	12.4	8.9	9.0	9.7	10.3	11.1	..	2500-2550	No
317	No*	28.0	..	0.29	74	0.12	9.4	12.4	8.9	9.0	9.7	10.3	11.1	..	2500-2550	No
321	No*	28.0	..	0.29	72	0.12	9.3	12.8	9.3	9.5	10.3	10.7	11.2	..	2550-2600	No
347	No*	28.0	..	0.29	73	0.12	9.3	12.8	9.3	9.5	10.3	10.6	11.1	..	2550-2600	No
405	Yes	29.0	..	0.28	60	0.11	..	..	6.0	6.4	6.7	7.5	..	..	2700-2790	No
410	Yes	29.0	..	0.28	57	0.11	14.4	16.6	5.5	5.6	6.4	6.5	..	..	2700-2790	Yes
416	Yes	29.0	..	0.28	57	0.11	14.4	16.6	5.5	5.6	6.4	6.5	..	..	2700-2790	Yes
430	Yes	29.0	..	0.28	60	0.11	15.1	15.2	5.8	6.1	6.3	6.6	6.9	..	2600-2750	No

* Becomes slightly magnetic when cold worked.
† Very low change of magnetic permeability when cold worked.

Table 4—Room-Temperature Mechanical Properties

Wrought stainless steels—annealed condition—representative values

Type	Form	Tensile strength, psi	Yield strength (0.2% offset), psi	Elongation in 2 in., %	Reduction of area, %
303 } 303Se }	Bar	90,000	35,000	50	55
304	Sheet, strip*	85,000	35,000	50	..
	Plate†	85,000	30,000	60	70
	Bar	85,000	35,000	60	70
	Tube‡	90,000	42,000	67	..
304L	Sheet, strip	82,000	32,000	50	..
	Plate	82,000	27,000	60	70
309	Sheet, strip	90,000	45,000	45	..
	Plate	95,000	40,000	45	65
	Tube	95,000	45,000	40	..
310	Sheet, strip	95,000	45,000	45	..
	Plate, bar	95,000	45,000	50	65
	Tube	85,000	44,000	53	..
316	Sheet, strip	90,000	40,000	50	..
	Plate	85,000	35,000	55	..
	Bar	80,000	30,000	60	70
	Tube	84,000	44,000	70	..
316L	Sheet, strip	87,000	37,000	50	..
	Plate	82,000	32,000	55	..
317	Sheet, strip	90,000	40,000	45	..
	Plate, bar	85,000	40,000	50	..
321	Sheet, strip	90,000	35,000	50	..
	Plate	85,000	30,000	55	..
	Bar	85,000	35,000	55	65
	Tube	86,000	46,000	58	..
347	Sheet, strip	95,000	40,000	45	..
	Plate	90,000	35,000	50	..
	Bar	90,000	35,000	50	65
	Tube	86,000	46,000	58	..
405	Sheet, strip	65,000	40,000	25	..
	Plate	65,000	40,000	30	..
	Tube	70,000	40,000	30	..
410	Sheet, strip	65,000	35,000	25	..
	Plate	70,000	35,000	30	..
	Bar	75,000	40,000	35	70
	Tube	75,000	40,000	25	..
416 } 416Se }	Bar	75,000	40,000	30	60
430	Sheet, strip	75,000	45,000	25	..
	Plate	75,000	40,000	30	..
	Tube	75,000	45,000	25	..

* Sheet and strip include thicknesses under 3/16 in.

† Plate thicknesses are 3/16 in. and over.

‡ Small cold-finished tubes will tend to have lower strength properties, large hot-finished tubes higher.

solution.

The presence of molybdenum in Types 316 and 317 and their low-carbon modifications leads to general highest corrosion resistance among the stainless steels and to the greatest high-temperature strength as well.

Physical Properties

The physical properties of most of the wrought stainless steels recognized in Section II of the ASME Boiler and Pressure Vessel Code are shown in Table 3. The properties are representative for steels in the annealed condition.

Mechanical Properties at Room Temperature

In Table 4 are presented representative room temperature mechanical properties of the wrought stainless steels which are recognized in Section II of the ASME Boiler and Pressure Vessel Code. Room-temperature mechanical properties of the cast steels are given in Table 5. Except where noted, properties are for steels in the annealed condition, in compliance with general practice in the use of these alloys.

Mechanical Properties at Elevated Temperatures

Modern industry uses stainless-steel pressure vessels under high stresses for long periods at elevated operating temperatures. Strength to withstand these stresses is obtained by the addition of alloying elements. At room temperature and slightly above, carbon serves adequately as a strengthener of steels. As the operating temperature is increased, carbon alone becomes less effective and the addition of chromium, often with molybdenum, tungsten or columbium, is needed for effective increase in operating temperature strength. At temperatures somewhat above 1000° F, even these additions yield no marked improvements and it is necessary to add nickel or some strong austenite-forming element to form an austenitic steel. The strength of the austenitic steels can be increased even further by the addition of small amounts of molybdenum, columbium and tungsten.

Mechanical Properties at Subatmospheric Temperatures

Modern industry uses many pressure vessels in processes in which the vessels are stressed or subjected to shock loading at temperatures far below normal atmospheric ranges. Such processes include refrigeration of frozen foods, production of synthetic rubber and the production and handling of liquid gases.

As temperature is decreased, the tensile strength, yield strength and hardness of metals and alloys are increased. The ductility of ferritic stainless steels decreases markedly with decrease in temperature. On the other hand, the austenitic stainless steels, in the annealed condition, retain their ductility to temperatures approaching absolute zero. This type of service is one for which they are most valuable. One must, however, be aware of the fact

Table 5—Room-Temperature Mechanical Properties

Cast stainless steels—annealed condition—representative values

Grade	Wrought alloy type (approx.)	Tensile strength, psi	Yield strength (0.2% offset), psi	Elongation in 2 in., %	Hardness, Brinell
CA 15*	410	100,000	75,000	30	185
CF 8	304	77,000	37,000	55	140
CF 8M	316	80,000	42,000	50	156/170
CF 8C	347	77,000	38,000	39	149
CH 20	309	88,000	50,000	38	190

* Air cooled from 1800° F, tempered at 1400° F.

Table 6—Low-Temperature Mechanical Properties of Certain Stainless Steels (Annealed Condition)

	Nominal properties				
Grade and type	*+70° F*	*+32° F*	*−40° F*	*−80° F*	*−320° F*
Type 304					
Yield strength, psi	35,000	34,000	34,000	34,000	39,000
Tensile strength, psi	88,000	130,000	155,000	170,000	246,000
Elongation in 2 in., %	62	55	47	39	32
Reduction of area, %	71	68	64	63	55
Izod impact, ft-lb	110	110	110	110	110
Type 316					
Yield strength, psi	38,000	39,000	41,000	44,000	70,000
Tensile strength, psi	78,000	90,000	104,000	118,000	180,000
Elongation in 2 in., %	60	60	59	57	46
Reduction of area, %	76	75	75	73	64
Izod impact, ft-lb	110	110	110	110	110
Type 347					
Yield strength, psi	40,000	42,000	44,000	45,000	51,000
Tensile strength, psi	84,000	105,000	117,000	130,000	195,000
Elongation in 2 in., %	60	62	63	57	40
Reduction of area, %	72	72	71	70	64
Izod impact, ft-lb	110	110	110	110	110
Type 410					
Yield strength, psi	87,000	89,000	90,000	94,000	148,000
Tensile strength, psi	110,000	115,000	122,000	128,000	158,000
Elongation in 2 in., %	21	24	23	22	10
Reduction of area, %	68	69	64	60	11
Izod impact, ft-lb	85	40	25	25	5
Type 430					
Yield strength, psi	38,000	40,000	41,000	44,000	87,000
Tensile strength, psi	65,000	69,000	76,000	81,000	90,000
Elongation in 2 in., %	37	37	36	36	0
Reduction of area, %	73	72	72	70	4
Izod impact, ft-lb	35	20	10	8	2

that the welded joints of these steels will not display ductility and impact values equal to those of the wrought members.

Deposited weld metal is essentially a cast structure, and extreme care must be taken in the choice of the electrode and in the actual welding to approach the condition of the base metal. The ASME Code recognizes this phenomenon, and requires impact tests on samples of deposited metal in the welded joint, but not of the base metal itself at temperatures lower than −20° F. The behavior of quenched and tempered martensitic steels, not covered by the Code, is intermediate between the other two groups. Figure 1 shows the relative behavior of the various types of stainless steels.

The nominal mechanical properties of representative stainless steels at various temperatures from 70 to −320° F are given in Table 6.

Corrosion Resistance of Stainless Steels

Chromium-Iron Alloys

The martensitic stainless steels (typified by Type 410) have useful resistance to a number of mild corrosives and particularly to alkaline solutions. They are resistant to a number of strong oxidizing environments such as concentrated nitric acid at moderate temperatures and are resistant to progressive scaling at temperatures up to 1200° F. They are used in numerous applications in the handling of high-temperature steam. Type 410 stainless shows good resistance to a number of sulfur-bearing environments at elevated temperatures and frequently is used for the lining of fractionating towers and other vessels in petroleum refining. Welded vessels in such applications usually are annealed to maintain ductility at welds. The ferritic alloy, Type 405, frequently is preferred for the construction of vessels of this type because it is much less subject to hardening when air-cooled from welding temperatures. The corrosion resistance of Type 405 is substantially the same as that of Type 410.

The ferritic stainless steels (typified by Type 430) are considerably more resistant to corrosion than Type 410, because of their higher chromium content. They are resistant to progressive scaling in oxidizing atmospheres at temperatures up to about 1500° F and to hot sulfur-bearing environments. Type 430 stainless is used to a considerable extent for the fabrication of equipment in the manufacture of nitric acid by the ammonia oxidation process. To provide a maximum combination of corrosion resistance and ductility in heat-affected areas of fabricated equipment in this service, a chromium content of 15–16% and carbon content of 0.10% maximum is sometimes specified. In other cases requiring a great deal of welded fabrication, a titanium-containing modification (Type 430T) may be used to provide more ductile welds in the as-welded condition. Type 430 stainless has satisfactory resistance to most natural atmospheres except marine atmospheres.

Austenitic Chromium-Nickel Stainless Steels

The austenitic chromium-nickel stainless steels are resistant to a large variety of corrosive media. Due primarily to the chromium content, they perform best under oxidizing conditions which are most harmful to ordinary steel and to many of the nonferrous metals and alloys. The addition of nickel to the

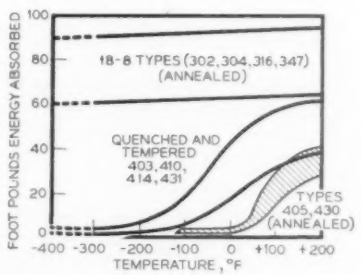


Fig. 1 Low-temperature impact data —Charpy keyhole notch. General behavior of austenitic, quenched and tempered martensitic, and nonhardenable ferritic stainless steels with respect to impact properties at subatmospheric temperatures

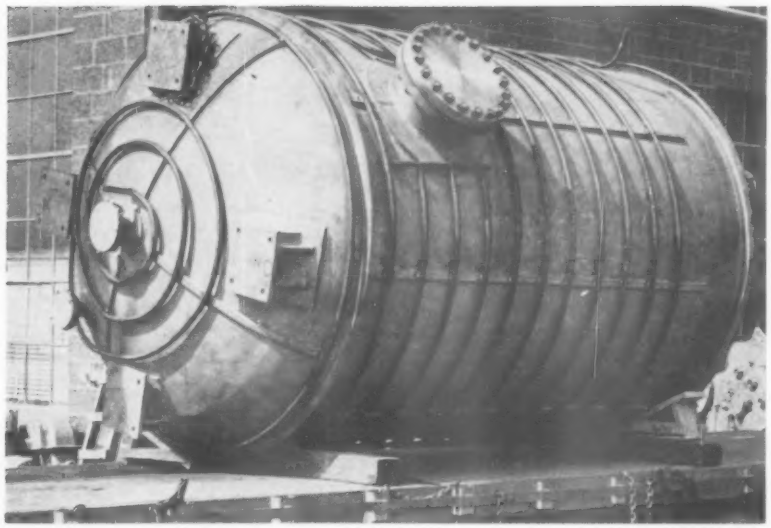


Fig. 2 Stainless-steel reactor, Type 316, 90 in. ID x 10 ft 3 in. straight shell $^{29}/_{32}$ in. thick, with ellipsoidal heads; ASME Code construction for 300 psi at 450° F; external steel coil attached to stainless supports, vessel heat treated and welds X-rayed

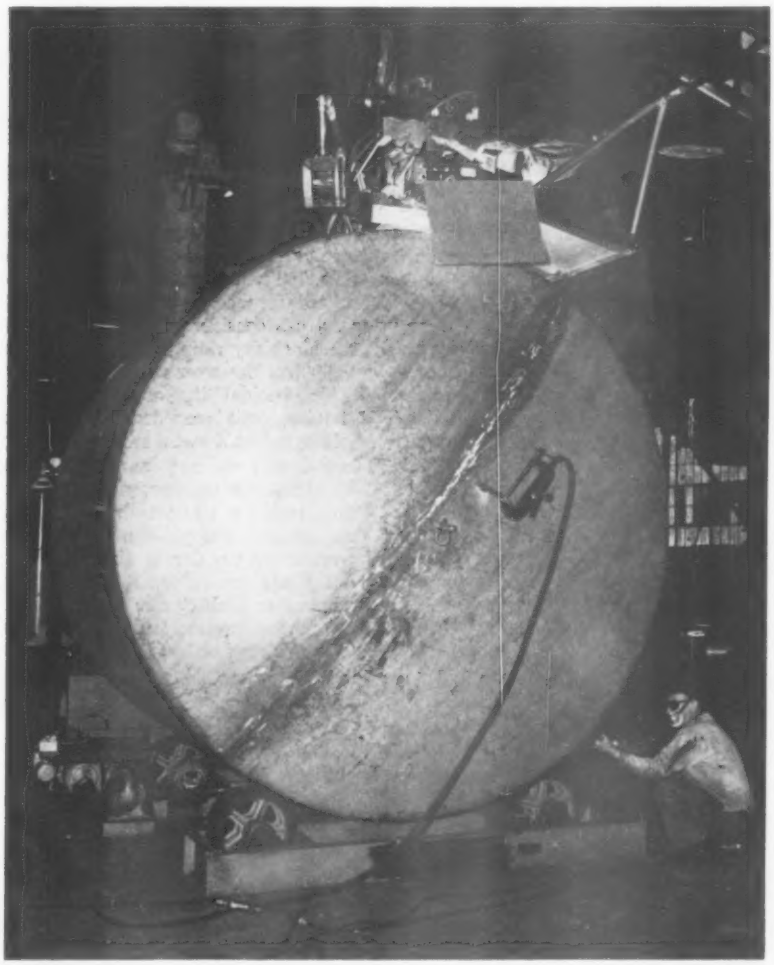


Fig. 3 Automatic welding of liquid oxygen storage tank, Type 304 stainless steel, 30,000 gal capacity, 10 ft 6 in. OD x $^{3}/_{16}$ in. thick

stainless steels adds to the passivating effects of chromium in oxidizing solutions such as nitric acid and at the same time improves the resistance of the alloys to reducing conditions. Nickel also has indirect effects related to its roles in promoting the desirable austenitic structure and in maintaining such a structure during and following the heating and cooling to which the alloys may be subjected during manufacture, fabrication and use.

Types 302 and 304 stainless are equivalent in corrosion resistance in many environments. Because of the higher carbon content of Type 302, this alloy is more subject to intergranular attack in some corrosives due to carbide precipitation resulting from heat of welding, so that it is common practice to use Type 304 in the construction of welded equipment to be used in such environments. Moreover, Type 302 is not recognized by the ASME Code for pressure vessel construction. In a limited number of corrosive environments, Type 304 stainless also is subject to intergranular attack due to carbide precipitation. For the construction of welded equipment in such cases, use is made of alloys which have been stabilized by the addition of columbium, as in Type 347, or of titanium, as in Type 321, or by lowering the carbon content to 0.03% maximum as in Type 304L, or by heat treatment of the standard grades.

These alloys are commonly used to handle oxidizing acid solutions such as those containing nitric acid and nitrates, peroxides, chromates and cupric, ferric and mercuric sulfates. They also are used with a variety of organic acids and compounds at moderate temperatures as in the food, dairy, pharmaceutical and textile industries. They normally are not resistant to reducing acid conditions as in hot sulfuric, phosphoric or hydrochloric acids.

Types 309 and 310 stainless and their modifications are used mainly for resistance to oxidation and sulfidation at high temperatures. Their resistance to corrosive solutions is somewhat similar to Type 304 although they sometimes show improved resistance, because of higher alloy content, to some highly oxidizing solutions such as boiling nitric acid.

The addition of molybdenum to the chromium-nickel stainless steels, as in Types 316 and 317, expands the passivity range, reduces the tendency to pitting attack, and considerably improves corrosion resistance in such mineral acids as sulfuric, sulfurous and phosphoric at moderate temperatures, in neutral chloride solutions and in hot strong organic acids such as acetic, lactic, maleic and fatty acids. These alloys also may be subject to intergranular attack in a limited number of cor-

rosives due to carbide precipitation resulting from heat effects of welding. In such cases, use may be made of low-carbon modifications, Types 316L and 317L, for the construction of welded equipment, or of the columbium-stabilized form designated as Type 318 (316Cb). Figure 2 shows a Type 316 stainless-steel reactor vessel.

The stainless steels usually are not used with halogen salts since they may be subject either to rapid general attack or to severe local attack in pits or crevices. The austenitic stainless steels are subject to stress-corrosion cracking if stressed in halogen environments. The ferritic stainless steels are less subject to stress corrosion cracking than the austenitic alloys but are more subject to cracking due to hydrogen embrittlement if stressed in solutions containing nascent hydrogen.

Design Factors

The "Maximum Allowable Stress Values in Tension for High-Alloy Steel, in Pounds per Square Inch" are given in Table UHA-23 of the ASME Boiler and Pressure Vessel Code, Section VIII—Unfired Pressure Vessels, 1956 Edition.

Design factors involving selection of proper alloys for corrosion resistance under service conditions, determination of proper surface condition, proper heat treatment and even increased thicknesses of materials to compensate for expected corrosion are not within the scope of the Code. These problems are, however, real and much within the responsibilities of the designer. In the case of the stainless steels, especially, the matter of corrosion resistance may be of prime importance.

Other factors within the control of the designer can also affect service. For example, the condition of the metal surface can affect the corrosion resistance of a vessel. Higher finishes and smooth surfaces free from all defects and scrupulously clean of all oil and grease have highest corrosion resistance. In the design of the vessel itself, places where residues and foreign matter might collect should be avoided. Contact between dissimilar materials should be minimized or avoided.

The designer should assist the user in assuring suitable service life for the vessel by designing to avoid excessive evaporation and permit good agitation so that uniform concentrations can be maintained. Design of heating devices to avoid possibilities of overheating with resulting burning, loss of corrosion resistance through carbide precipitation, or excessively active chemical reaction is important.

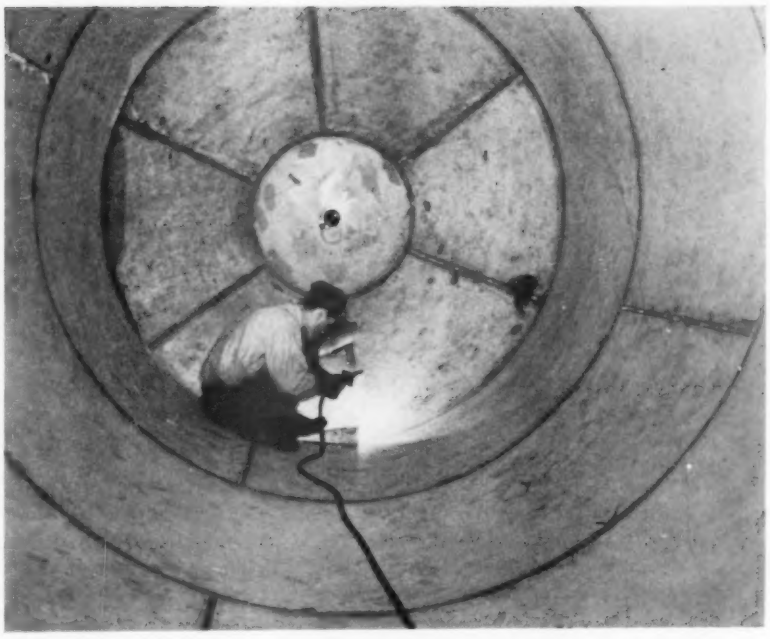


Fig. 4 View inside conical end of 6000-gal storage tank, Type 304 stainless steel 7 ft 6 in. OD x $^3/_8$ in thick

Fabrication

The stainless steels have, generally, excellent workability. Any metal has special rules for best fabrication and stainless steel is no exception. While it is, of course, impossible to detail all the rules of fabricating stainless steels, some comparison between its behavior and that of mild steel may be of interest.

The higher strengths of the stainless steels require greater power in forming and most working operations. The work hardening characteristics of the austenitic grades of stainless steel further add to the power requirements. Modifications in die design may be necessary to compensate for greater springback. Ironing should be avoided. In many cases, however, the added power requirements do not prohibit forming on available equipment.

In machining operations the toughness as well as strength of stainless steels results in a certain amount of "gumminess." Free machining types, as permitted for bolting material, eliminate this to a considerable extent and have machinability ratings of as much as 85 to 90% of Bessemer screw stock.

The weldability of the austenitic stainless steels is excellent. Weldments, joints and weld metal are strong, tough and ductile and require no subsequent heat treatment to improve their physical properties for Unfired Pressure Vessel applications, except to relieve residual stresses set up during the welding of heavy sections. Figures 3 and 4 show manual and automatic welding processes in use in vessel fabrication of Type 304 stainless steel.

STRENGTH OF BRAZED JOINTS IN COPPER ALLOYS

Room-temperature strength of lap and butt-type joints in copper alloys, brazed with various filler metals, is determined through laboratory investigation

BY W. H. MUNSE AND J. S. ALAGIA

SYNOPSIS. This paper presents the results of an investigation to determine the strength of lap and butt-type joints in copper alloys, brazed with various filler metals and tested at room temperature. The copper alloys were copper-silicon (ASTM B96 Alloy A), copper-nickel 70–30 (ASTM B171), copper-nickel 90–10 (ASTM B111) and aluminum bronze (ASTM B171 Alloy D); the filler metals used were BAg-1, BAg-6, BCuP-5 and BCuP-4 as classified under the present AWS-ASTM Specification. In the preparation of the lap joint specimens, BCuP filler metals were not used with the copper-nickel alloys; the butt joints were prepared with BAg-1 filler metal only.

Introduction

The object of this study was to determine the room-temperature strength of joints in several copper alloys, brazed with various filler metals.

In a previous study, sound brazed lap joints in copper invariably fractured through the base metal.[1] Since the copper alloys of this study are much stronger than the copper of the previous study, the lap joint design used in the preceding program (approximately 0.15 in. lap) was considered to be suitable to study the shear strength of the copper alloy joints.

While this investigation is concerned with a number of the factors affecting the joint strength, the emphasis is on the strength of the braze. Because of the lack of sufficient information, the present procedure of providing a lap three times the thickness of the connected material is arbitrary and probably uneconomical. Therefore, this study was planned to provide a more rational basis for the design of brazed joints in copper alloys, as well as an indication of the procedures that should be used to obtain sound joints.

The copper alloys included in the study are copper-silicon, copper-nickel (70–30), copper-nickel (90–10) and aluminum bronze. Lap joints, both with and without fillets, were prepared with these copper alloys and with four representative filler metals: BAg-1, BAg-6, BCuP-4 and BCuP-5. However, the last two filler metals were not used with the copper-nickel alloys. In addition, butt-joints of each of the base metals were prepared with BAg-1 only.

It is essential that uniform heating be provided for sound brazing of copper and copper alloy joints. However, since the alloys of this study have relatively poor conductivity,[4] an additional study was made of several slow heating procedures using BAg-1 as the filler metal.

Description of Specimens and Tests

Description of Materials

(*a*) *Base Metals*—The four $^1/_4$-in. thick copper alloys tested in this program were certified to meet the requirements of ASTM designations B-96, B-111, and B-171 as reported in Table 1A. The mechanical properties at room temperature were ascertained from tensile tests of coupons cut from the parent plates of each alloy. A sketch of the coupon specimens and the average results of the tests are shown in Fig. 1*a* and Table 1B respectively.

It is well-known that the mechanical properties of copper and copper alloys may change when the metals are heated for brazing, depending upon the temperature and length of heating time. However, for the brazing temperatures and brazing times used in these tests, the changes would be relatively small.[9] Therefore, the strengths in Table 1B may be considered representative for the material in the brazed joints.

Table 1—Properties of Base Metals

(A) Chemical Composition in Percentage (ASTM)*

Base metal	*Cu, min*	*Si*	*Mn, max*	*Zn, max*	*Fe, max*	*Pb, max*	*Ni, max*	*Al*
Copper-silicon alloy B-96-55 Alloy A	94.8	2.8–3.6	1.5†	1.5†	1.6†	0.05†	0.6†	...
Copper-nickel (70–30) B-171-55	65	...	1.0	1.0	0.7	0.05	29–33	...
Copper-nickel (90–10) B-111-55	86.5	...	1.0	1.0	0.5–2.0	0.05	9–11‡	...
Aluminum-bronze B-171-55 Alloy D	88–92.5	...	..	..	1.5–3.5	...	...	6–8

(B) Mechanical Properties§

Base Metal	*Yield stress at 2% offset, psi*	*Yield stress at 5% strain, psi*	*Ultimate stress, psi*	*Elongation in 2-in. gage, %*	*Reduction in area, %*
Copper-silicon alloy	21,340	25,680	64,000	59.8	64.9
Copper-nickel (70–30)	26,900	26,520	60,800	42.1	37.6
Copper-Nickel (90–10)	22,720	24,440	46,800	45.3	69.3
Aluminum bronze	55,540	55,700	87,000	42.2	69.0

* Minimum sum of the percentages should be 99.5%.
† One or more of these elements may be present within the limits specified.
‡ Cobalt is included in nickel percentage.
§ The results are averages of two coupon tests.

W. H. Munse is Research Professor of Civil Engineering, University of Illinois, Urbana, Illinois, and J. S. Alagia was formerly graduate student in Civil Engineering at the University of Illinois.

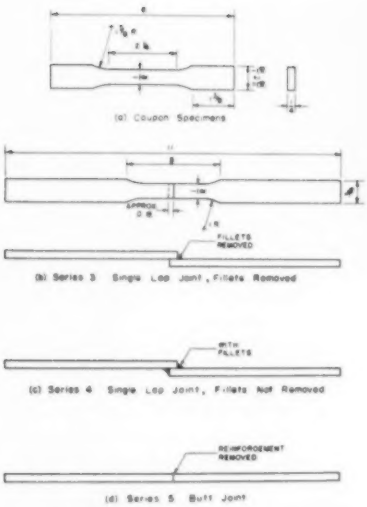

(a) Coupon Specimens
(b) Series 3 Single Lap Joint, Fillets Removed
FILLETS REMOVED
WITH FILLETS
(c) Series 4 Single Lap Joint, Fillets Not Removed
REINFORCEMENT REMOVED
(d) Series 5 Butt Joint

Fig. 1 Specimens for tests of copper alloys

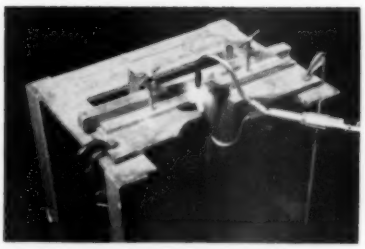


Fig. 2 Torch brazing of lap joints

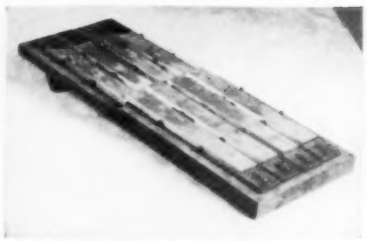


Fig. 3 Jig for furnace brazing

Table 2—Summary of Filler-Metal Properties

Series	AWS-ASTM designation	Chemical composition, % Cu	Ag	Zn	Cd	P	Solidus (temperature, ° F)	Liquidus (temperature, ° F)	Brazing temperature range, ° F
1	BAg-1	15	45	16	24		1125	1145	1145–1400
2	BAg-6	34	50	16			1270	1425	1425–1600
3	BCuP-5	80	15			5	1185	1500	1300–1500
4	BCuP-4	87	6			7	1185	1380	1300–1500

The brazing properties of these materials, as discussed in the AWS Brazing Manual,[4] are given below.

"The copper-silicon alloys are readily brazed if adequate flux protection is supplied to prevent the formation of refractory silicon oxides. This metal must be in a stress-free condition during brazing in order to avoid stress cracking, which may otherwise occur in the presence of molten filler metal. Stress relief may be accomplished by slow, careful application of the brazing heat."

This material is hot short and an assembly should be supported during the brazing cycle in a manner which will minimize any severe strain on the material.

"The aluminum bronzes may be brazed if special care is taken to clean and flux properly. A minimum heating time is necessary to avoid excessive diffusion of aluminum with the brazing filler metal, resulting in a formation of a brittle joint interface. This condition is more pronounced in higher aluminum content bronzes."

"The copper-nickel alloys can be readily brazed by any of the standard processes. This material must be used in a stress-free condition during brazing in order to avoid stress cracking which may otherwise occur in the presence of molten filler metal. Stress relief may be supplied by slow, careful application of brazing heat."

(*b*) *Filler Metals*—The filler metals were received from three different suppliers: BAg-1 from the first supplier, BAg-6 from the second, and BCuP-4 and BCuP-5 from the third. All of the filler metals were in wire form, 1/16 in. diam. The paste-type flux used with each filler metal was that recommended and furnished by the supplier of the filler metal. However, a special "aluminum bronze" flux was used for all aluminum bronze specimens. Table 2 gives the specified chemical composition and brazing temperature range for each of the filler metals.

The AWS Brazing Manual[4] makes the following statements concerning these filler metals.

"Brazing filler metals of the BAg classifications are used for joining all ferrous and non-ferrous metals, except aluminum, magnesium and other metals which have too low a melting temperature. They are used with all brazing processes and are generally free flowing when molten. Joint clearances should be between 0.002 to 0.005 in. (in a finished joint at room temperature) for best distribution of the filler metals in the joint by capillary attraction. Flux is generally required."

"BAg-1 and -1a brazing filler metals are free flowing and low melting. They are used for general purpose work. Their melting ranges are very narrow. The color after brazing is light yellow."

"BAg-5 and -6 filler metals are general purpose metals for use with higher brazing temperature. They may be used where the use of cadium-containing alloys might be prohibited as for food handling equipment. The color after brazing is light yellow."

"Brazing filler metals of BCuP classifications are used primarily for joining copper and copper alloys with some limited use on silver and molybdenum. Because their phosphorus content will form brittle iron or nickel phosphides, these filler metals are not recommended for (more than 5%) ferrous or nickel-bearing metals. They may be applied by all brazing processes and may be used without flux for some applications on copper and silver. However, better results may be expected when a flux is used. Flux is necessary when BCuP filler metals are used with copper alloys."

"These filler metals have a tendency to liquate if heated slowly. It is important, therefore, especially if the filler metal is preplaced, to apply heat as rapidly as possible. The color after brazing is light gray. Immersion in 10% sulfuric acid will restore the copper color."

"BCuP-4 brazing filler metal is best used with clearances of 0.001 to 0.003 in. (in a finished joint at room temperature)."

"BCuP-5 brazing filler metal is particularly adaptable where very close fits cannot be held. Joint clearances of 0.003 to 0.005 in. are recommended."

Specimen Preparation—Pre-brazing Operations

(*a*) *Lap Joints*—Copper-alloy sheets 1/4 in. thick, approximately 60 in. long and 6 in. wide were used for these tests. Strips approximately 7/8 in. wide and

Fig. 4 Lap joint with extensometer in position

6 in. long were cut from these sheets with the axis of the strips perpendicular to the 60-in. length of the base plate. Before brazing, approximately 1 in. of one face of each strip, at the end to be joined, was lightly filed and polished with 2/0 emery cloth to remove the oxidized surface as well as foreign matter. The polished area was then wiped clean with carbon-tetrachloride to insure removal of all oil, grease or dirt.

The strips were set in the brazing fixture shown in Fig. 2. with the gap set between 0.002 and 0.005 in. using a feeler gage. The clamp holding the lower strip in place was then released, the strip removed from the jig, and a thin uniform layer of well-mixed liquid flux brushed over a length of approximately 1 in. on both clean surfaces. The lower piece was replaced and, after the lap of 0.15 in. had been set with a clean gage, clamped in its original position. The specimen was then ready to be brazed.

(*b*) *Butt Joints*—The cutting and machining of the pieces for the butt joints was in general the same as for the lap joints. The machined ends were wiped clean with carbon tetrachloride and the pieces aligned in the brazing jig, one piece being tightly clamped and the other abutting it but loosely clamped. The loose piece was then removed and well-mixed liquid flux was applied in a thin uniform layer to both of the surfaces to be joined. The piece was then replaced as before and the specimen was ready to be brazed.

Specimen Preparation —Brazing Operations

(*a*) *Main Series, Lap Joints*—A medium light-weight dual-tip multi-flame No. 5 torch was used with tips set approximately $1^1/_2$ in. apart and facing each other as shown in Fig. 2. By means of a 2-stage regulator, constant oxygen and acetylene pressures were used throughout the brazing operations; oxygen 20 psi and acetylene 2.5 psi. The torch was then adjusted to give a neutral flame.

The heating procedure was developed to achieve as uniform a temperature in the joint as possible. The heating was started on both strips approximately 2 in. away from the joint and gradually worked towards the center as the torch was moved back and forth from one strip to the other. The torch was centered vertically over the joint so that both pieces were heated in the same general manner. When the temperature of the joint was within the brazing range, the operator moved the torch to one side so as not to place the flame directly on the filler metal and touched the filler metal which had been cleaned and fluxed to the end of the joint. If the filler metal flowed immediately, the torch was removed from the specimen and the wire was fed to the joint until the joint had been formed. If the filler metal failed to flow, it was removed and a little additional heat was applied to the joint and the same process repeated until the proper flow of the filler metal was obtained. The brazing time, from the start of the heating to the removal of the filler wire, was recorded and found to range from 13 to 20 sec depending on the type of specimen.

(*b*) *Main Series, Butt Joints*—The brazing operations for the butt joints followed the same general procedure as for the lap joints. As soon as the brazing was complete, the finger-tight clamp was loosened. The brazing time varied from 10 to 15 sec. As with the lap joints, when the molten braze solidified, the specimen was removed from the jig and visually inspected.

(*c*) *Slow-Heat Series*—The joints included in the slow-heat study were of the lap type and prepared either by torch or furnace brazing. Because of the increase in length of heating time, the amount of oxide formation increased and more flux was required than for the main series of specimens.

In the torch brazing operations, No. 1, No. 2 and No. 5 dual-tip torches were used with their tips set approximately $1^1/_2$ in. apart and inclined at 20 deg to a line connecting the tips. The procedure was the same as for the main series, except that with the No. 5 torch, the flame was intermittently removed to let the specimen achieve a more uniform distribution of temperature. As a result, the brazing time was increased to two or three times that used in brazing the main series specimens.

For the furnace brazing, the filler wire was cleaned and cut into pieces approximately $^3/_4$ in. long. Each piece was then dipped into the proper flux and preplaced at the upper end of the joint (see Fig. 3). When the temperature of the furnace reached 100° F above the lower limit of the brazing range,[4] the jig with four specimens was slid into the furnace. The joints were checked from time to time and the jig was removed from the furnace as soon as the filler metal flowed into the joint. The time required for the brazing was 20 to 25 min.

Post-brazing Operations

After brazing, the specimens were air-cooled to room temperature, immersed in water to loosen the flux, and then brushed to remove the loose flux.

The specimens were machined to a $^1/_2$ in. width in the test section and, where specified, the fillets were removed. For the butt joints, the surfaces were lightly filed to remove the excess reinforcement from the faces and edges of the joints.

The laps were measured with a special measuring device which utilized a dial indicator. The laps, though originally set at 0.15 in., were found to have increased to 0.17–0.19 in. When the fillets were removed, the lengths generally decreased to 0.16–0.18 in.

Description of Tests

The specimens were tested at room temperature in a 120,000 lb universal hydraulic testing machine. For the tests of lap joints, the jaws in the testing machine were offset $^1/_4$ in. in opposite directions to facilitate the gripping of the specimen.

A measure of the deformation in the

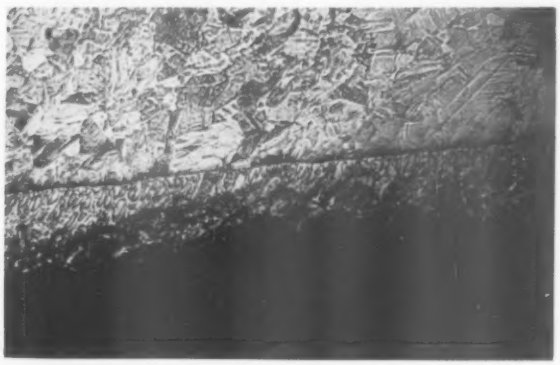


Fig. 5 Typical filler-metal fracture of copper-silicon lap joint. X 200

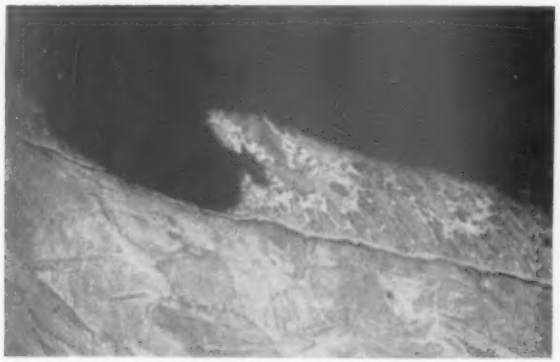


Fig. 6 Interface fracture of copper-silicon lap joint brazed with BAg-6. X 200

Table 3—Ultimate Strengths of Lap Joints*

Base metal	Fillets	Average strength, psi, for various filler metals: BAg-1	BAg-6	BCuP-5	BCuP-4
Copper-silicon	No	30,930	32,660	37,030	28,710
	Yes	43,870	41,350	35,790	29,480
Copper-nickel (70–30)	No	39,660	36,660	..	..
	Yes	45,090	48,720	..	..
Copper-nickel (90–10)	No	34,670	33,820	..	..
	Yes	44,850	43,790	..	..
Aluminum-bronze	No	33,020	35,570	41,880	34,200
	Yes	50,930	47,880	43,810	44,900

* All values are the average of five tests.

Table 4—Ultimate Strengths of Butt Joints*

(BAg-1 Filler Metal)

Base metal	Average ultimate tensile strength, psi
Copper-silicon	35,060
Copper-nickel (70–30)	50,890
Copper-nickel (90–10)	41,370
Aluminum-bronze	33,040

* All values are the average of five tests.

lap joints during the tests was obtained with the help of the extensometer shown in Fig. 4. The mountings were designed so that the elongation of the base metal would not, in general, effect greatly the deformation. However, the bending of the joint resulting from the eccentricity in loading probably had some effect on the readings. Nevertheless, these dial readings provided a qualitative means of comparing the relative behavior or deformation of the different types of materials and joints.

Analysis and Discussion of Test Results

Factors Affecting the Strength of a Brazed Joint

A number of factors may be expected to affect the strength of a brazed joint loaded in tension. These factors are briefly discussed below for three locations of fractures: (A) base metal, (B) filler metal, or (C) interface.

(A) *Fracture partly or wholly through the base metal.*

1. The strength of the base metal in the joint.[1] The strength of the joint depends on the physical properties of the base metal. However, because of the heating cycle, the base-metal strength in the joint may be somewhat less than it is before brazing.

(B) *Fracture partly or wholly through filler metal.*

2. The strength of filler metal in the joint.[3] In this case, the strength of the joint depends, in part, on the properties of the filler metal after brazing.
3. Porosity and flux inclusions.[2,4] Unless the porosity and inclusions cover more than 10 to 15% of the brazed area, the decrease of strength due to their presence is not significant. For greater percentages of porosity, the reduction in strength increases rapidly.
4. The lateral constraint offered to the filler metal by the base metal.[2] The lateral constraint produces an increase in the filler-metal strength and thus affects the strength of the joint; the effect of this constraint increases with decreasing thickness of the braze. Consequently, the joint strength also increases with decreasing joint thickness, unless the gap becomes too thin to permit satisfactory flow of the filler metal in the joint.

(C) *Fracture partly or wholly through interface.*

5. The properties of bond.[4] In case of alloying bond, the properties of the alloy formed and the extent of interlocking at the interface affects the strength of the joint. If the bond is adhesive, the amount of molecular attraction is a main factor affecting the joint strength.
6. Porosity and flux inclusions. These flaws may reduce the area of bond and thus reduce the joint strength.

Results of Tests

(*a*) *Main Series*—The results of the tests of the main series are briefly summarized in Tables 3 and 4. The strengths of some of these joints exhibited a considerable amount of scatter. However, the strengths for the following types of joints were found to be consistent within a range of about ±10%. (1) Copper-Silicon Alloy—Lap joints with and without fillets, brazed with BCuP-5 and BCuP-4 filler metals, (2) Copper-Nickel (70–30)—Lap joints without fillets and butt joints, brazed with BAg-1 filler metal, (3) Copper-Nickel (90–10)—Lap joints without fillets and butt joints, brazed with BAg-1 filler metal, and (4) Aluminum Bronze—Lap joints without fillets brazed with BAg-1 and BCuP-5 filler metals.

The remaining groups of identical specimens exhibited variations which were somewhat greater than ±10%. However, for some types of joints

Fig. 7 Filler metal fracture of copper-nickel (70–30) lap joint brazed with BAg-1. X 200

Fig. 8 Typical fracture of a copper-nickel (70–30) lap joint. Fracture in filler metal and interface. X 200

Table 5—Results of Slow-Heat Series—Lap Joints, No Fillets

(BAg-1 Filler Metal)

Brazing method	*Base metal*	*Average ultimate strength, psi*
Furnace brazing	Copper-silicon	31,230
	Copper-nickel (70–30)	33,120
	Copper-nickel (90–10)	33,130
	Aluminum-bronze	31,190
Slow intermittent heat No. 5 torch	Copper-nickel (70–30)	39,660
	Copper-nickel (90–10)	34,830
Slow heat brazing No. 2 torch	Copper-nickel (70–30)	37,070
	Copper-nickel (90–10)	34,430
Slow heat brazing No. 1 torch	Copper-nickel (70–30)	38,860
	Copper-nickel (90–10)	32,240

there were a number of consistent results with one or two joints which exhibited a relatively large variation in strength.

(*b*) *Slow-Heat Series*—The results obtained from the specimens brazed with the slow heating processes are summarized in Table 5. These results are generally consistent and fall within the range of strengths obtained from the similar specimens in the main series.

(*c*) *Scatter Series*—In some of the main series of identical specimens, even though the first three specimens were fairly consistent, a relatively large variation was found in the strength of the next few specimens tested. This raised a question as to the consistency or reliability of the average strengths reported. Consequently, a short series of tests was conducted to study the consistency of the test results.

The results of the scatter series are summarized in Table 6 and partly answer the questions on consistency. When eight additional lap joint specimens without fillets (BAg-1 filler metal) were tested for each base metal, the strengths of the copper-nickels and the copper-silicon specimens were found to be consistent with those of the respective identical specimens in the main series (Table 3), but the strengths of aluminum bronze specimens, ranged from as low as 9470 psi to 33,700 psi and were quite inconsistent. The fractures of most of these specimens showed cast filler metal layers which were partly unbounded or contained a considerable degree of porosity. In a search for the cause of the low strengths, several specimens were reversed and rebrazed. In the rebrazing operations it was noted that the operator was not removing the torch from the specimen when the filler metal was being fed. This caused excessive oxide formation and a large non-uniform black fillet at the joint. When the procedure was corrected, large, clean, uniform, white fillets were obtained. When tested, these specimens were found to be sound and much stronger; they had strengths of 35,400 psi and 37,700 psi.

Metallurgical Studies

The scope of the metallurgical investigation was such that the causes of specific fractures were not emphasized. Instead, the investigation was carried out to detect gross differences in structures that might be contributing factors influencing the general performance of the brazed joints.

The base metals were single-phase structures that had been recrystallized after or during rolling. Because these alloys undergo no phase change, the only structural change upon heating would be grain growth. However, no evidence of grain growth was observed in the base-metal structures. This was not unexpected because of the short duration of the heating cycle. In addition, three of the base metals contained a slight amount of iron which has an inherent tendency to inhibit grain growth. Thus, the heating effect in the specimen preparation had a negligible influence on the physical properties of the base metals. However, the base metals, particularly the copper-nickel alloys, revealed extensive segregation.

An examination of the fractures of some of the joints of the copper-silicon alloy indicates that, in general, they failed through the filler metal (see Fig. 5). However, one of the lap joints without fillets and brazed with BAg-6 failed primarily at the interface (see Fig. 6). A study of some of the copper-nickel (70–30) joints reveals that although one lap joint brazed with BAg-1 fractured through the filler metal (see Fig. 7), each of the other joints studied, exhibited a fracture which ran through both the filler metal and the interface (see Fig. 8). Every joint of copper-nickel (90–10) that was studied showed a combined filler metal-base metal-interface fracture (see Fig. 9) except one lap joint brazed with BAg-1. This latter specimen failed through the filler metal (see Fig. 10).

An examination of the joints of aluminum bronze showed a wide variety in types of fractures. The lap joints brazed with BAg-1 and BAg-6 fractured through the filler metal (see Figs. 11 and 12) and the butt joints fractured through the filler and base metal (see Fig. 13). The specimens brazed with BCuP-5 failed at the interface (see Fig. 14), while those brazed with BCuP-4 exhibited filler metal failures (see Fig. 15).

A limited study of a few joints which

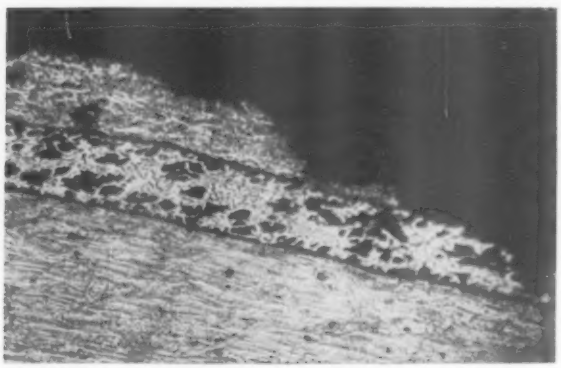


Fig. 9 Typical fracture of copper-nickel (90–10) lap joint. X 200

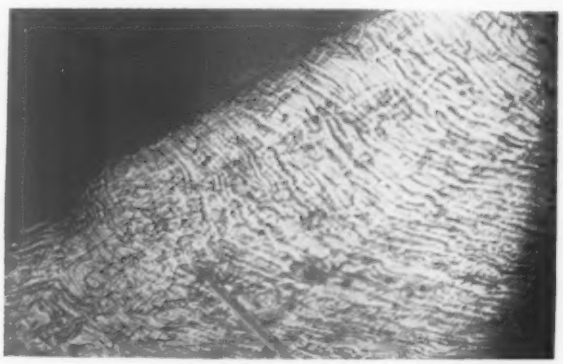


Fig. 10 Filler-metal fracture of copper-nickel (90–10) lap joint brazed with BAg-1. X 200

had been loaded to the maximum strength but wherein the fractures were incomplete indicated that the fractures were initiated at the ends of the lap. If a joint had fillets with porosity, the fracture passed through the porosity. A typical joint where fracture initiated at the ends through the porosity is shown in Fig. 16.

In general, the porosity in the joints that were studied appeared to be less than 10% of the joint area; the joints which had higher percentages of porosity also had thinner gaps. The percentage of voids in the fillets was observed to be two to three times that in the lap. However, no inclusions were noticed.

In general, the gap as determined from the micrographs, was about 0.0025 in. However, the specimens of aluminum bronze showed gaps as great as 0.004 to 0.0098 in. In joints which were otherwise identical, the specimens with higher strengths corresponded to the thinner gaps.

Analysis of Results

A comparison of the limited metallurgical studies and the results of the tests of main series indicates that, in general, the strengths of the joints which failed exclusively in the filler metal or at the interface are fairly consistent. However, the strengths of the other joints which exhibited combined fractures showed a larger scattering in the results. It is interesting to note further that, in general, the strengths of joints with fillets showed a relatively wide scatter; however, the corresponding joints without fillets exhibited relatively consistent strengths.

Possible explanations of these behaviors may be obtained from a study of the factors described earlier as affecting the strengths of the joints. It is evident that if the fracture is entirely through one part of the joint, the strength will depend on fewer factors and thus will be less likely to vary, than if it passes through one or both of the remaining sections of the joint. In any case, the largest scatter would be expected if the fractures passed through the filler metal since the factors which affect the strength of a joint which fails partly or wholly through the filler metal are many and sometimes hard to control. However, when thin gaps are one of the principal causes of porosity, the decrease in strength due to the porosity is counteracted by the increase in strength resulting from the thinner gap. This may help to explain the consistent results generally obtained for the joints which failed in the filler metal.

The behavior of the joints with combined fractures can also be analyzed on the basis of the probable cause of such a fracture. It is possible that such joints may have had a weak porous filler metal at the ends of the lap or at the sections through which the fracture progressed, and a sound filler metal in those portions of the joint where the fracture was forced into the interface or base metal. If this condition exists, the stresses resulting from the porosity may be far from uniform and thus cause the scatter in strengths of such joints.

The scatter in strength of the joints with fillets can be explained to a large extent by the porosity noted in the metallurgical studies. These studies showed extensive porosity in some of the fillets which probably caused the initiation of fractures at a relatively low load.

Table 6—Summary of Test Results Scatter Series Lap Joints Without Fillets

(All joints brazed with BAg-1)

Specimen no.	*Base metal*	*Ultimate strength, psi*
3A1C-6	Copper-silicon alloy	33,690
3A1C-7	Copper-silicon alloy	11,860*
3A1C-8	Copper-silicon alloy	37,890
3A1C-9	Copper-silicon alloy	34,900
3A1C-10	Copper-silicon alloy	31,710
3A1C-11	Copper-silicon alloy	34,000
3A1C-12	Copper-silicon alloy	23,080
3A1C-13	Copper-silicon alloy	24,750
		31,430
3B1C-6	Copper-nickel (70–30)	38,360
3B1C-7	Copper-nickel (70–30)	36,840
3B1C-8	Copper-nickel (70–30)	38,060
3B1C-9	Copper-nickel (70–30)	38,110
3B1C-10	Copper-nickel (70–30)	38,250
3B1C-11	Copper-nickel (70–30)	34,550
3B1C-12	Copper-nickel (70–30)	41,780
3B1C-13	Copper-nickel (70–30)	40,290
		38,280
3C1C-6	Copper-nickel (90–10)	32,190
3C1C-7	Copper-nickel (90–10)	33,620
3C1C-8	Copper-nickel (90–10)	33,900
3C1C-9	Copper-nickel (90–10)	34,600
3C1C-10	Copper-nickel (90–10)	35,880
3C1C-11	Copper-nickel (90–10)	33,820
3C1C-12	Copper-nickel (90–10)	34,140
3C1C-13	Copper-nickel (90–10)	32,280
		33,800
3F1C-6	Aluminum-bronze	19,340
3F1C-7	Aluminum-bronze	12,000
3F1C-8	Aluminum-bronze	33,700
3F1C-9	Aluminum-bronze	13,800
3F1C-10	Aluminum-bronze	9,470
3F1C-11	Aluminum-bronze	15,430
3F1C-12	Aluminum-bronze	17,370
3F1C-13	Aluminum-bronze	16,290

* Considerable porosity—not included in average.

Effect of Base Metal

A study of the effect of the base metal on the strength of the lap joints is shown in Fig. 17 and reveals that the lap joints of copper-silicon had the lowest average strengths for all of the materials tested. The average strengths of the copper-nickel (90–10) lap joints were somewhat higher than those of the copper-silicon joints. However, the difference in strength of the joints of the various base metals was not very great.

The strengths of the butt joints brazed with BAg-1 are shown in Fig. 18. The joints of copper-nickel (70–30) had the highest average strength, and those of aluminum bronze had the lowest average strength. The average strengths of the butt joints of copper-silicon were somewhat higher than those of aluminum bronze butt joints, but were lower than those of copper-nickel (70–30) butt joints. However, it should be noted that the scatter is such that the differences between the strengths of joints of different base metals are negligible.

The effect of base metal on the deformation of the brazed joints was studied in the tests also. In general, the joints in aluminum bronze deformed very little before fracturing. The joints

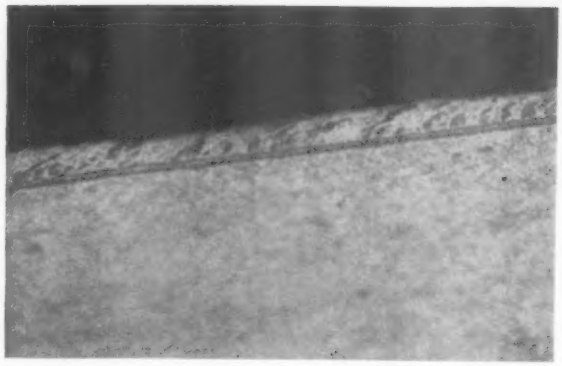


Fig. 11 Filler-metal fracture of aluminum-bronze lap joint brazed with BAg-1. X 200

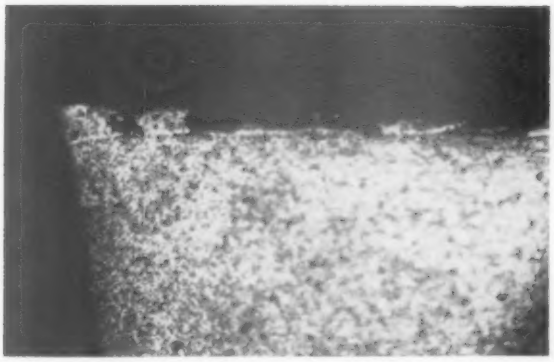


Fig. 12 Filler-metal fracture of aluminum bronze lap joint brazed with BAg-6. X 200

in the three remaining base metals all exhibited similar stress-deformation relationships; those in copper-nickel (90–10) appeared to deform somewhat more than did those of copper-silicon, but the latter deformed more than the joints of copper-nickel (70–30). Thus, it appears that the deformation as measured in these tests was determined to a large extent by the properties of the base metals. The slip or deformation measurements indicated that all of the base metals yielded except the aluminum bronze. Consequently, the deformation of the aluminum-bronze joints at failure was largely in the filler metal.

Effect of Filler Metal

A study of the variation in the strength of the joints with the filler metal is shown in Fig. 19. An analysis of this figure shows that the average strengths of the lap joints without fillets prepared from copper-silicon and aluminum bronze were highest for joints brazed with BCuP-5; and were lowest for joints brazed with BAg-1 and BCuP-4. The joints brazed with BAg-6 had somewhat higher strengths than those brazed with BAg-1 and BCuP-4 but exhibited somewhat more scatter in strength. When the fillets were left in place, the average strengths of the lap joints brazed with BAg-1 were higher than those of lap joints brazed with BAg-6, BCuP-4, or BCuP-5.

The average strength of the copper-silicon lap joints with fillets, was lowest when they were brazed with BCuP-4; however, the corresponding aluminum-bronze joints had a little higher strength than the aluminum-bronze BCuP-5 joints with fillets. The average strengths of the copper-nickel joints were higher for joints brazed with BAg- than for those brazed with BAg-6, except in the case of the copper-nickel (70–30) lap joints with fillets. It should be noted, however, that if we take into account the scatter, the effect of filler metal may be considered negligible in most instances.

Effect of Joint Type

A study of Figs. 17 and 19 reveals that, in general, the average strengths and the extreme values of strength were higher for joints with fillets than for joints without fillets. This, however, was not true for joints brazed with BCuP-5 and BCuP-4. These joints had strengths of nearly the same order when tested with fillets and without fillets. They were found to have relatively small fillets; consequently, the increase in strength due to the presence of the fillets was small and, in some cases, negligible.

Since the fillets add to the shearing area of the joint, a greater strength may be expected from the joints with fillets. However, it should be noted that some of the fillets were found to have a high percentage of porosity which caused stress concentrations and thus failure at a lower load than expected. Even then it was found that in many cases, joints with fillets had strengths roughly in proportion to the total area.

Effect of Fabrication Procedure

A sound fabrication procedure is necessary for all types of brazed joints if the joints are to be fully effective; the importance of the procedure cannot be over-emphasized. The cleaning of the materials before brazing, the application of flux, the setting of the gap, and the brazing operations must be effectively controlled.

In order to study the effect of variations in heating operations, the slow-heat series was included in the program. The results, as discussed previously, were quite consistent and fell in between the range of strengths obtained from similar specimens in the main series of tests. This is an indication that non-uniform heating in the brazing of the main series may have been one of the principal factors causing the variations in the results.

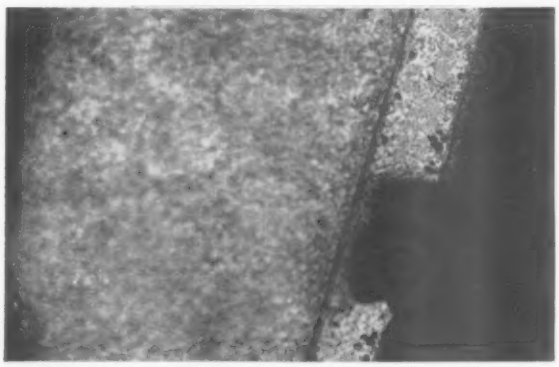


Fig. 13 Filler metal-base metal fracture of aluminum-bronze butt joint brazed with BAg-1. X 200

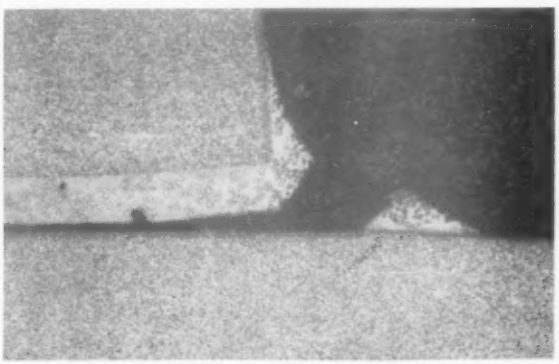


Fig. 14 Interface fracture of aluminum-bronze lap joint brazed with BCuP-5. X 200

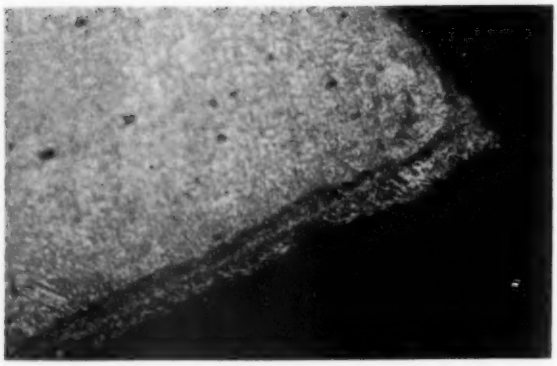


Fig. 15 Filler-metal fracture of aluminum-bronze lap joint brazed with BCuP-4. X 200

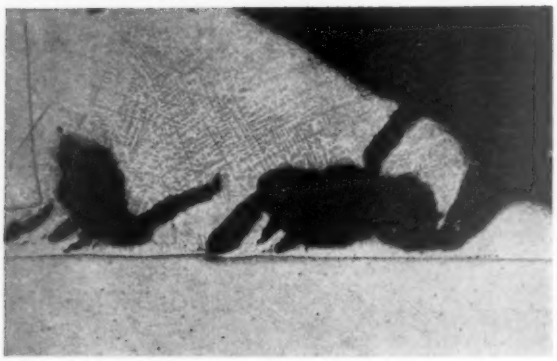


Fig. 16 Typical lap joint in which fracture initiated through porosity in fillets. X 200

The results of the scatter series on aluminum bronze show that the direct heating of the joint with the torch should be carefully avoided when the filler metal is being deposited. The flame caused an excessive formation of oxide and a large non-uniform fillet. Thus, the details of the fabrication procedure must be carefully controlled if sound brazed joints are to be produced.

Summary and Conclusions

Summary of Test Results

The tests discussed herein may be summarized briefly as follows:

(*a*) The average strengths (in psi) of the lap joints without fillets and the butt joints are summarized in Tables 3 and 4.

(*b*) When the fillets were not removed, the average strengths of the joints brazed with the BCuP filler metals were of the same order of magnitude as those of the corresponding lap joints without fillets. However, the scatter in the results was somewhat greater. The presence of fillets in joints brazed with BAg-1 and BAg-6 increased the average strengths roughly in proportion to the area added by the fillets.

(*c*) Specimens with fillets experienced greater deformation before failure than those without fillets.

(*d*) Specimens of aluminum bronze exhibited relatively small deformations before failure when compared with the joints of the other base metals.

Conclusions

The following conclusions are based on the results of the tests summarized herein.

(*a*) Suitable fabrication procedures are essential if sound brazed joints are to be obtained in the copper alloys of this program with BAg-1, BAg-6, BCuP-4 and BCuP-5 filler metals.

(*b*) On the basis of the strengths obtained in these tests of four base metals and various filler metals, the lengths of lap necessary to develop the full tensile strengths of the base metals with sound joints would be approximately as follows:

	Lap length, in multiple of thickness			
	BAg-1	*BAg-6*	*BCuP-5*	*BCuP-4*
Copper-Silicon	2.07	1.96	1.73	2.23
Copper-nickel (70–30)	1.53	1.66	...	...
Copper-nickel (90–10)	1.35	1.38	...	...
Aluminum-bronze	2.63	2.45	2.08	2.54

Acknowledgments

The tests described in this report were a part of an investigation resulting from a cooperative agreement between the Engineering Experiment Station of the University of Illinois and the Copper and Brass Research Association.

This work was done as a part of the Structural Research Program of the Department of Civil Engineering under the general direction of Professor N. M. Newmark, Head, Department of Civil Engineering. The study was conducted by J. S. Alagia, graduate student in Civil Engineering, under the immediate supervision of W. H. Munse, Research Professor of Civil Engineering. The metallurgical studies were made by R. Batista and T. Harris, students in the Department of Mining and Metallurgical Engineering, working under the direction of R. W. Bohl, Associate Professor of Metallurgical Engineering.

The specimens and scope of the program were planned with the assistance of an Advisory Committee consisting of the following persons: Arthur N. Kugler, Chairman, L. W. Hawthorne, Vice-Chairman, A. I. Heim, Secretary, B. A. Hackett, Robert J. Metzler, N. M. Newmark, A. Stanley Cross, Jr., S. A. Greenberg, T. E. Velfort, J. J. Vreeland.

The assistance and advice of this group is gratefully acknowledged.

Bibliography

1. Munse, W. H., and Crawford, D. C., "Filler Metal Strengths in Brazed Copper Joints," The Welding Journal, February 1955.
2. Bredzs, Nikolajs, "Investigation of Factors Determining Tensile Strengths of Brazed Joints," The Welding Journal, November 1954.
3. Handy and Harman, Technical Bulletins.
4. Committee on Brazing and Soldering, AWS "Brazing Manual," 1955.
5. *Welding Handbook*, Third Edition, American Welding Society, New York (1950).
6. Rhyne, C., Jr., "Factors Controlling the Strength of Brazed Joints From Final Report N. R. C. 560," The Welding Journal, July 1946.
7. "Quick Test Eliminates Brazing Defects," Iron Age, August 31, 1950.
8. Damon, S., "Is Furnace Brazing Just as Good?" American Machinist, April 2, 1951.
9. Damon, S., "Effect of Brazing Temperature on Base Metal Properties," Iron Age, August 25, 1949.
10. *ASTM Specifications*, 1955, Part II.

INVESTIGATION OF THE MECHANICAL PROPERTIES OF METAL-ARC WELDED Ti – 6% Al – 4% V

Investigation shows that Ti – 6% Al – 4% V has satisfactory properties in the as-welded condition when matching filler and base metals are used

BY DANIEL M. DALEY, JR., AND CARL E. HARTBOWER

ABSTRACT. The purpose of this investigation was to evaluate (1) the tensile and notch-bar impact properties of a Ti – 6% Al – 4% V *weld deposit* prepared by the inert-gas-shielded tungsten-arc process using a single heat of Ti-Al-V as both filler and base material and (2) the notch toughness of the *heat-affected zone* in Ti – 6% Al – 4% V as produced by the inert-gas-shielded consumable-electrode process.

The properties of the deposited weld metal were evaluated in 1/4-in. weldments using subsize tensile and impact specimens. The notch toughness of heat-affected zone was evaluated in 1/2-in. weldments by means of the Watertown Arsenal Laboratories (WAL) composite impact specimen. The latter specimen consists of a standard V-notch Charpy impact specimen cut from a bead-on-plate weldment so that the test area is one-half deposited weld metal and one-half heat-affected base metal. The relative notch toughness of weld and heat-affected base metal is determined by measuring the lateral deformation occurring in each half of the specimen.

Data indicated that Ti – 6% Al – 4% V will have satisfactory properties in the as-welded condition when using matching filler and base metal. The tensile joint efficiency was approximately 100% with an ultimate strength of 150,000 psi. The notch toughness of deposited Ti-Al-V weld metal was considered acceptable at this strength level, and the notch toughness of the heat-affected zone was found to exceed that of any other commercially available alpha-beta alloy previously evaluated.

Daniel M. Daley, Jr., is Welding Engineer and **Carl E. Hartbower** is Physical Metallurgist, Watertown Arsenal, Watertown, Mass.

Presented at 1956 AWS National Fall Meeting in Cleveland, Ohio, October 17-21.

The opinions or assertions contained herein are the private ones of the authors and are not to be construed as official or reflecting the views of the Ordnance Corps.

Introduction

Statement of the Problem

There is a continuing search for light-metal alloys of higher strength and toughness. Precipitation-hardening aluminum alloys such as 24S and 75S are used extensively but suffer from three limitations: (1) they have only moderately good strength (approximately 75,000 psi ultimate), (2) when welded in heavy sections, the *maximum* as-welded joint efficiency is only 60 – 70% and (3) the aluminum alloys are seriously deficient in strength at operating temperatures in excess of 500–600° F. Titanium has attracted considerable attention in the last few years because of its appreciably greater strength (150,000 psi as-welded ultimate tensile strength is not uncommon), near 100% tensile weld-joint efficiency and sustained strength at service temperatures of 600 – 700° F. The Ti – 6% Al – 4% V alloy, for example, is one of the most promising of the new commercially available alloys. As a base metal, it has good strength (over 130,000 psi yield) and satisfactory notch toughness (15 ft-lb or greater at −40° C) in the as-rolled annealed condition.

Other commercially available titanium alloys have room-temperature tensile properties comparable to those of the Ti – 6% Al – 4% V alloy but most, if not all, suffer severe embrittlement in the heat-affected zone and in the deposited weld metal (when the filler and base metal are matching in chemical composition). Investigations at the Battelle Memorial Institute have shown that the maximum *total* content of beta-stabilizing elements is 3 – 4% for acceptable ductility and notch toughness in titanium-alloy weld deposits.[1] The extent of heat-affected zone embrittlement has been dramatically brought out in researches at Rensselaer Polytechnic Institute by synthetically reproducing the thermal cycles of weld heat-affected zones using a time-temperature controller.[2] V-notch Charpy-impact values for heat-affected structures corresponding to peak temperatures of 1400 – 2400° F, tested at 0° C, are shown in Table 1. The performance of Ti – 6% Al – 4% V is

Table 1—Comparison of Impact Strengths of Titanium (Alloys Subjected to RPI Synthetic-Specimen Technique)

Average Charpy V-notch impact strength (ft-lb at 0° C) after exposure to thermal cycles with peak temperatures as indicated

Ti-alloy	*Base metal as-received*	*Heat-affected zone peak temperature* 1400° F	1600° F	1800° F	2000° F	2200° F	2400° F
6% Al – 4% V*	22	20	19	23	21	18	18
7% Mn – 0.07% C†	16	10	5	6	7	6	6
7% Mn – 0.14% C†	11	4	3	3	2	2	2
3% Al – 5% Cr‡	33	25	13	12	8	7	7

* E. F. Nippes and J. M. Gerken, "Notch Sensitivity of Weld Heat-Affected Zones of a 6% Al – 4% V Titanium," Final Rept. Ord. Con. DA-30-115-ORD-(P)-642, WAL Rept. No. 112/86-7, October 1955.

† E. F. Nippes and J. M. Gerken, "Notch Sensitivity of the Weld Heat-Affected Zones in Two 7% Mn Titanium Alloys Containing 0.14% C and 0.07% C," Interim Rept. No. 4, Ord. Con. DA-30-115-ORD-490, WAL Rept. No. 112/86-6, March 1955.

‡ E. F. Nippes and J. M. Gerken, "Notch Sensitivity of the Weld Heat-Affected Zones in a 5% Cr – 3% Al Titanium Alloy," Interim Rept. No. 2, Ord. Con. DA-30-115-ORD-490, WAL Rept. No. 112/86-4, November 1954.

Table 2—Materials Investigated and Their Chemical Analysis*

Material	Heat	C	O	H	N	Fe	Al	Sn	V
		%							
Ti – 6% Al – 4% V	M1801D	0.03	0.116	0.0050	0.020	0.15	5.95	..	4.01
Ti – 5% Al – 2.5% Sn	D30540B	0.07	0.101	0.0069	0.024	0.12	4.82	2.33	..
RC55 (1/16-in. electrode)	T5-5095	0.08	0.095	0.010	0.042	0.13	..	..	..
Ti – 6% Al – 4% V	Weld†	0.06	0.153	0.0070	0.028	0.35	5.69	..	3.34
Ti – 5% Al – 2.5% Sn	Weld†	0.07	0.112	0.0042	0.040	0.25	4.89	2.38	..

* Chemical analysis, except for oxygen and hydrogen, was made by Lucius Pitkin, Inc., under Ordnance Contract No. DA-30-069-ORD-636. The oxygen and hydrogen analysis was made by the National Research Corp. under Ordnance Contract No. DA-19-020-ORD-3682, using the Walter technique of vacuum fusion analysis.

† Tungsten-arc weld deposits.

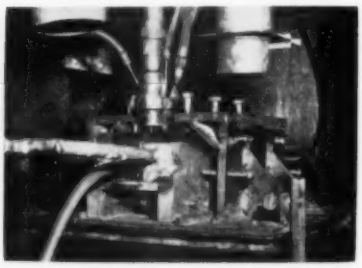


Fig. 1 Inert-gas-shielded tungsten-arc equipment used for preparing weldments in 1/4-in. plate

outstanding; even at a testing temperature of −40°, all heat-affected structures but one absorbed 15 ft-lb or more of impact energy (the 1400° F peak-temperature structure absorbed 13 ft-lb at −40°).

Scope of Investigation

Because Ti – 6% Al – 4% V was in short supply for welding studies at the time this investigation was conducted, evaluation of this alloy as a welding material was restricted to one heat of Ti – 6% Al – 4% V in two thicknesses (1/4 and 1/2 in).

Tensile joint efficiency and notch toughness of deposited weld metal was evaluated in 1/4-in. tungsten-arc weldments using matching filler and base metal. For purposes of comparison, a limited number of tests were also conducted on a single heat of Ti – 5% Al – 2.5% Sn alloy to determine the weld tensile strength and notch toughness of an all-alpha titanium alloy. The toughness of the Ti – 6% Al – 4% V heat-affected zone was determined by depositing unalloyed filler (Ti-Al-V was not available as wire at the time this investigation was conducted) in 1/2-in. plate by means of the consumable-electrode process using the Watertown Arsenal Laboratories (WAL) composite impact specimen.

Chemical analyses for the materials used during this investigation are listed in Table 2. The chemical analyses for deposited weld metal are also shown in Table 2.

Welding Procedures

Tungsten-Arc Process

Weldments were prepared in 1/4-in. plate material (double-V butt joint) using a 250-amp water-cooled welding head containing a 1/8-in. tungsten electrode (Fig. 1). The welding torch was mounted on a radiograph so that the arc-travel speed could be controlled. The amperages and voltages used during welding were automatically recorded. Beside inert gas issuing from the welding head (hereinafter called primary shield), auxiliary shielding was provided by means of a trailing shield and a backing fixture (for details see Ref. 3, Figs. 3 and 5).

Details of the tungsten-arc welding procedures follow:

(*a*) Joint design: 90-deg double-V butt with 1/16-in. root opening, using two passes in 1/4-in. plate.

(*b*) Meter readings: 300–335 amp; 70 v open and 29–31 v closed circuit voltage; direct current, straight polarity.

(*c*) Arc-travel speed: 12 ipm.

(*d*) Shielding: Primary, 85 cfh helium; trail, 100 cfh argon; backing, 100 cfh helium.

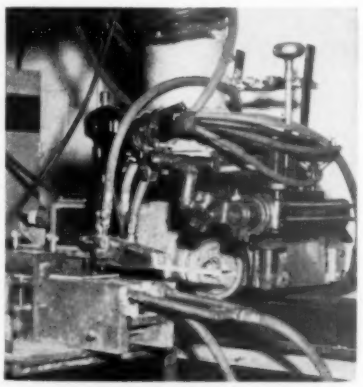


Fig. 2 Inert-gas-shielded consumable-electrode welding equipment used for preparing bead-on-plate weldments in 1/2-in. plate

A low interpass temperature (100 – 200° F) was maintained for all weldments. The inert gas used was a welding grade of the highest purity commercially available (99.92% argon and 99.95% helium.)

In preparing the tungsten-arc weldments, the filler material consisted of a strip (approximately 1/8 x 1/8 in.) taken from the base metal, thus giving the weld deposit the same nominal composition as the base metal.

Table 3—Tensile Properties in 1/4-In. Weldments

	Yield, strength, psi 0.1% offset	Yield, strength, psi 0.2% offset	Tensile strength, psi	Elongation, %	Reduction area, %	Location of break	Weld joint efficiency, %
Ti – 6% Al – 4% V							
Base metal*	131,850	134,400	149,250	12.5	43.5	...	...
Transverse weld	125,000	132,500	152,500	9.3	32.5	Weld deposit	102.0†
All-weld-metal	122,500	130,000	148,500	6.3	32.0	...	...
Ti – 5% Al – 2.5Sn							
Base metal*	121,630	122,130	135,880	17.3	41.3	...	...
Transverse weld	113,750	117,800	130,500	9.4	25.0	Weld deposit	96.0†
All-weld-metal	117,500	121,250	133,000	15.7	25.0	...	...

* Average of 2 values, all other data from single specimens.

† Weld joint efficiency = (Transverse weld tensile strength/Base metal tensile strength) × 100 = (152,500/149,250) × 100 = 102%.

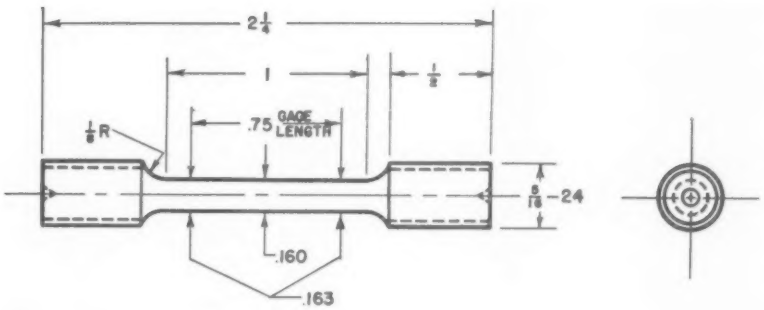


Fig. 3 Subsize tensile specimen

Consumable-Electrode Process

Bead-on-plate weldments were prepared using an automatic welding head mounted on a radiograph which controlled the arc-travel speed (Fig. 2). Welding amperages and voltages were automatically recorded. As in the preparation of the tungsten-arc weldments, the inert-gas protection was provided by means of primary, trailing and backing shielding.

Details of the welding procedure used for the consumable-electrode weldments follow:

(*a*) Joint design: Single-weld pass deposited in a groove ($^1/_2$-in. plate).
(*b*) Meter readings: 340 amp; 70 v open and 42 v closed circuit voltage; direct current, reverse polarity.
(*c*) Arc-travel speed: 12 ipm.
(*d*) Wire feed speed: 400 ipm (approximately).
(*e*) Shielding: Primary, 90 cfh helium + 10 cfh argon; trail, 100 cfh helium; backing, 100 cfh helium.

Because Ti – 6% Al – 4% V was not available in the wire size required for consumable-electrode welding, $^1/_{16}$-in. diam commercially pure titanium was used (see Table 2). Previous investigations at Watertown Arsenal Laboratoris (Hartbower and Daley, *loc. cit.*, and Ref. 4) have shown that unalloyed filler deposited in alloy base metal will produce weld deposits with strength somewhat undermatching the strength of the base metal but with superior notch-bar impact properties. Thus, weld deposits produced with the consumable-electrode process using unalloyed filler material have somewhat lower alloy content than the base metal, whereas the weld deposits produced with the tungsten-arc process using alloy filler (assuming no losses due to vaporization) have the same alloy content in the weld and base metals.

Tests and Results—Tungsten-Arc Weldments

Tensile Tests

The tensile properties of the $^1/_4$-in. tungsten-arc weldments were obtained by means of subsize tensile specimens (Fig. 3) taken both transverse and longitudinal to the weld deposits. The longitudinal specimens were cut so that the entire reduced section of the specimens consisted of deposited weld metal. The portion of the test specimen within the gage marks of the transverse specimens included both deposited weld metal and heat-affected base metal. Table 3 presents the tensile-test data. These data show that for weldments prepared using Ti – 6% Al – 4% V as both filler and base metal, a tensile joint efficiency of approximately 100% may be expected.

For comparison, the tensile properties of Ti – 5% Al – 2.5% Sn also are recorded in Table 3. Although the tensile joint efficiency of the all-alpha weldment was almost as high as the Ti – 6% Al – 4% V alloy, the strength of the Ti 5% Al – 2.5% Sn weld was 10,000–20,000 psi lower.

Notch-Bar Impact Tests

Notch toughness of the weld metal was determined by means of a modified V-notch Charpy impact specimen (Fig. 4) machined from $^1/_4$-in. weldments so that the section under the notch consisted entirely of deposited weld metal. The resulting transition curves are shown in Fig. 5. As in the case of the tensile evaluation, an all-alpha Ti-Al-Sn alloy has been included for purposes of comparison. The rather marked displacement between the transition curves for the Al-V weld and base metals is attributed to (1) the damaging effect of welding that has been found to

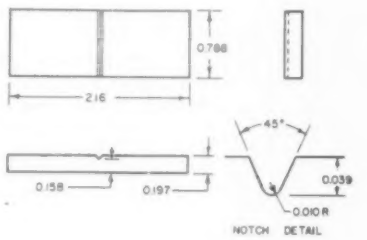


Fig. 4 Modified V-notch Charpy-impact specimen

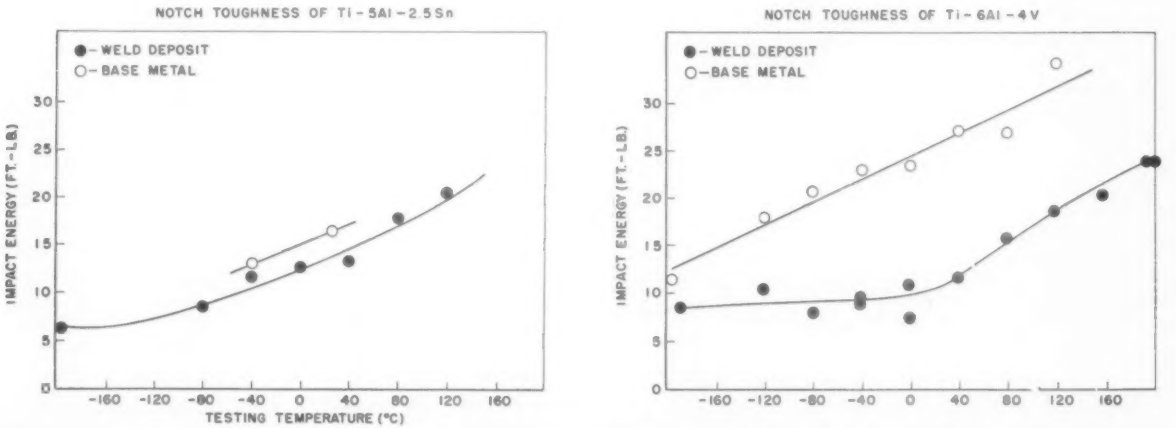


Fig. 5 Notch toughness of base materials and deposited weld metal using the modified V-notch Charpy-impact specimen

Specimens were taken from $^1/_4$-in. weldments prepared using the inert-gas-shielded tungsten-arc welding process.

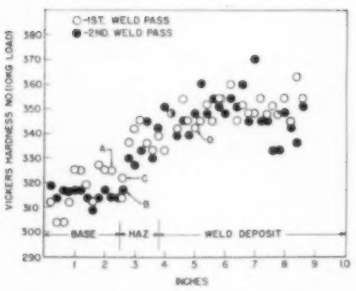


Fig. 6 Weld joint hardness survey for Ti – 6% Al – 4% V weldment prepared $^1/_4$-in. plate using the inert-gas-shielded tungsten-arc welding process

A, B, C, and D refer to locations of microstructure in Fig. 7. HAZ, heat-affected zone.

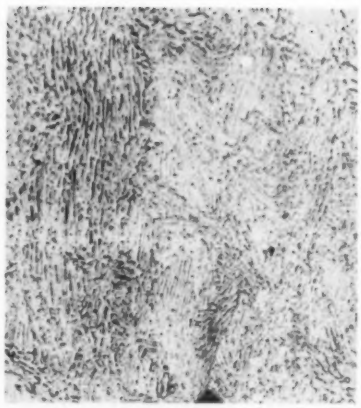
occur in the case of all titanium alloys containing beta-stabilizing elements in excess of 3%[5] and (2) the higher total interstitial content of the deposited weld metal (0.248 COHN in the deposited weld metal as compared to 0.171 COHN in the base metal). The all-alpha, Ti – 5% Al – 2.5% Sn, on the other hand, started with a lower level of toughness but suffered less damage from welding.

The 10 ft-lb transition temperature* for Ti – 6% Al – 4% V weld metal occurred at approximately 0° C; whereas, in the case of the all-alpha Ti – 5% Al – 2.5% Sn alloy, the 10 ft-lb transition temperature occurred at approximately −40° C. While this shows the all-alpha alloy to have greater as-welded toughness, the Al-V alloy had appreciably greater strength at this toughness level.

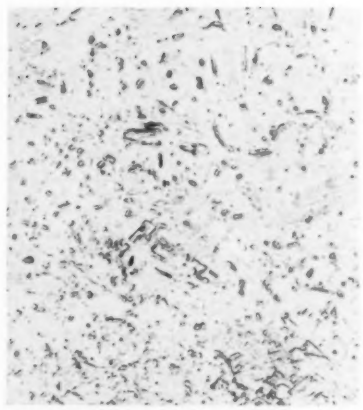
Hardness Tests

A Vickers hardness survey using a 10-kg load was made in a weld cross section of the $^1/_4$-in. weldment. Impressions were placed at 0.02-in. intervals starting in the unaffected base metal and traversing through the heat-affected zone into the deposited weld metal along a line approximately $^1/_{16}$-in. below the surface of the plate. Two such traverses were made, one through each of the two weld passes (designated as 1st and 2nd weld pass in Fig. 6) of the double-V butt joints. There was no significant difference between the hardness of the first and second weld passes. There was, however, a gradient of hardness in the heat-affected zone. Other commercial titanium alloys which have been investigated[4] developed a marked peak of hardness in the heat-affected zone rather

* Impact energy (10 ft-lb) has been used in previous investigations[3] as an arbitrary criterion of acceptable notch toughness. At approximately 10 ft-lb and below, the energy-temperature curves obtained by testing standard and modified V-notch Charpy bars are superimposed, i.e., there is approximately a 1:1 correlation between the test results obtained from the two types of specimens (see Fig. 21 of Ref. 3).

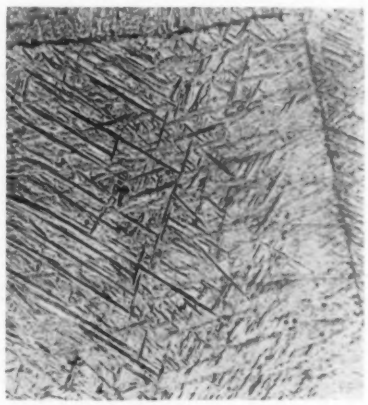


A. Base metal



B. Heat-affected zone. 2nd pass

C. Heat-affected zone. 1st pass



D. Weld metal

Fig. 7 Typical microstructure (X 500) for Ti – 6% Al – 4% V weldment prepared in $^1/_4$-in. plate using the inert-gas-shielded tungsten-arc welding process with matching filler and base metal

The letters A, B, C, and D locate the microstructure on the hardness curve shown in Fig. 6.

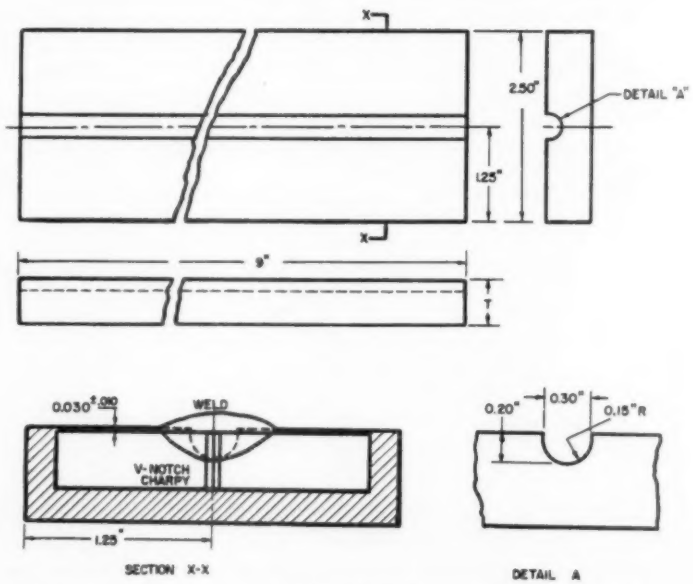


Fig. 8. Watertown Arsenal Laboratories' composite impact specimen

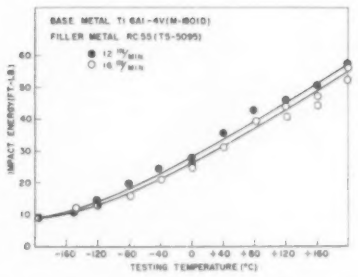


Fig. 9 Notch toughness of the composite weld joint

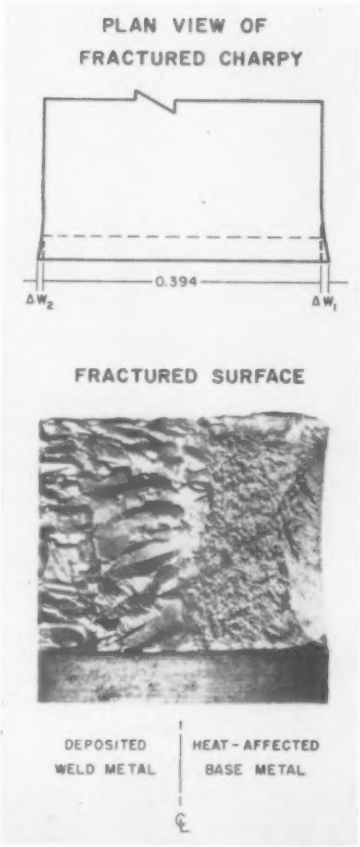


Fig. 10 Fracture surface and lateral deformation in a WAL composite V-notch Charpy specimen

This fracture surface illustrates an extreme case where, at the testing temperature, there was considerable ductility in the heat-affected base metal measured as increase in width (W_1) and almost no ductility in the deposited weld metal (W_2). This specimen was taken from a weldment produced by depositing Ti – 4% Cr – 2% Mo filler in Ti – 4% Cr – 2% Mo base metal using the tungsten-arc process. Deformation (lateral expansion) is measured by means of a comparator (X 30) using the undeformed sides of the test specimen as reference.

than the gradual rise shown in Fig. 6. Note that the hardness of the Ti – 6% Al – 4% V deposited weld metal was appreciably greater than the base metal (approximately 30 VHN higher), which was consistent with the higher interstitial content and microstructure of the weld deposit.

Microstructure Examination

Because of the marked difference between the notch toughness of the weld deposit and the base metal found in T – 6% Al – 4% V, an examination was made of the microstructure. Figure 7 shows typical microstructure observed in weldments prepared by means of the tungsten-arc process. The base metal, labeled *A*, consists of a fine aggregate of the alpha-beta phase. The photomicrograph, labeled *B*, was taken in the outer (low-temperature) heat-affected zone of the second pass, where the first evidence of microstructure change is evident. The islands of primary alpha show very little coalescing or growth. Photomicrograph *C*, representing a heat-affected structure in the first weld pass, illustrates the effect of multipass temperature. The islands of alpha have grown to several times their original size and show signs of transformation. Grain boundaries are now appearing and the alpha-prime needles are large and sharp. The microstructure of the deposited weld metal is labeled *D*. Here the grain-boundary alpha outlining prior beta grains are seen. There is mixed Widmanstatten and basket-weave alpha in a beta matrix. The large grains are a result of the high temperature and rapid cooling associated with welding.

Tests and Results— Consumable-Electrode Weldments

WAL Composite Impact Tests

The notch toughness of weld heat-affected zone was evaluated by means of the Watertown Arsenal Laboratories composite impact specimen.[6] This specimen enables simultaneous evaluation of the relative notch toughness of deposited weld metal and heat-affected base metal. The specimen is a standard V-notch Charpy impact bar cut from a bead-on-plate weldment so that the cross section under the notch is approximately one-half deposited weld metal and one-half heat-affected base metal (Fig. 8).

By means of the composite specimen, performance can be evaluated by two methods. The first method consists of a measurement of the *total energy* absorbed in fracturing the over-all weld joint, where the plot of impact energy vs. testing temperature represents an integration of the notch toughness characteristics of the deposited weld metal and the gamut of structures that make up the heat-affected base metal. Figure 9 is a plot of the total energy absorbed in fracturing the composite specimen vs. testing temperature. Note that little difference is

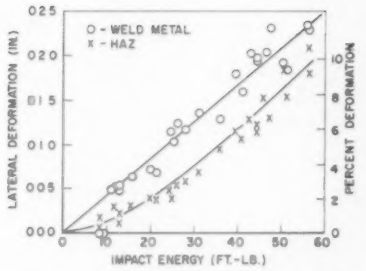


Fig. 11 Relationship between lateral expansion and impact energy

The lateral expansion is plotted separately for the deposited weld metal and the heat-affected base metal. The composite weldment was formed by depositing unalloyed titanium in 1/2-in. Ti – 6% Al – 4% V using the consumable-electrode process. (HAZ, heat-affected zone.)

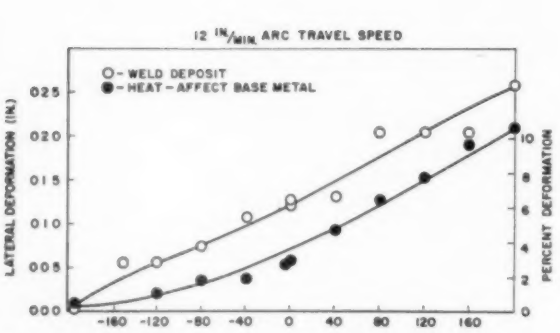
indicated between 12 and 16 ipm arc-travel speed. The 15 ft-lb transition temperature* occurs at approximately −100° C, indicating exceptional weld-joint toughness as compared with other alloy types previously investigated.[4] It should be kept in mind that the *energy-temperature* curves obtained with a composite specimen represent an integration of the notch toughness characteristics of the low-alloy weld metal and the gamut of structures contained in the heat-affected base metal.

The second method for evaluating performance with the composite specimen consists of a separate measurement of *lateral deformation* in the weld-metal half of the test specimen and in the heat-affected base-metal half of the test specimen (Fig. 10). This provides individual transition curves of deformation vs. testing temperature for weld metal and heat-affected base metal, where the latter represents an integration of the toughness characteristics of the gamut of structures contained in the heat-affected base metal.

The use of deformation in lieu of an energy measurement is based upon the fact that in titanium, as in steel,[4] there is a simple relationship between energy absorbed in fracturing the test bar and deformation (lateral expansion). Figure 11 illustrates this relationship. Note that at a given energy-to-fracture level there is an appreciable difference in the amount of deformation occurring in the two sides of the test specimen (e.g., at 15 ft-lb total energy there is approximately 3% lateral expansion in the weld-metal half and only 1% in the heat-affected base metal half of the test bar).

Figure 12 is a plot of the deformation as measured in each side of the test specimen vs. testing temperature.

* A 15 ft-lb energy level is used in connection with the heat-affected zone study to permit comparisons with the findings of other investigations.



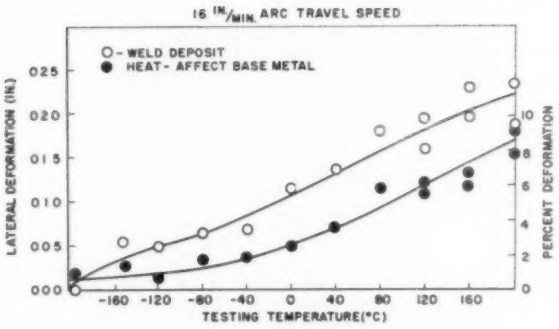


Fig. 12 WAL composite V-notch Charpy transition curves. Specimen taken from a $^1/_2$-in. bead-on-plate consumable-electrode weldment

Note that the transition temperature (based upon a more or less arbitrary deformation level of 2%) for the low-alloy weld metal is remarkably low (approximately −150° C) and that although the transition temperature of the heat-affected base metal is higher (−60° C at 12 ipm and −40° C at 16 ipm) it, nevertheless, is superior to any other alpha-beta alloy so far investigated.[4] From these results it is apparent that the low transition temperature indicated by Fig. 9 (15 ft-lb at −100° C) reflects the high notch toughness of the low-alloy weld deposit formed by depositing unalloyed wire in the Ti - 6% Al - 4% V base metal.

The 15 ft-lb transition temperatures for synthetically reproduced heat-affected structures in Ti - 6% Al - 4% V as determined by Rensselaer Polytechnic Institute[5] are of the same order of magnitude as the transition temperature for heat-affected base metal as determined by the WAL composite specimen. Table 4 presents data obtained by means of the RPI synthetic-specimen technique.

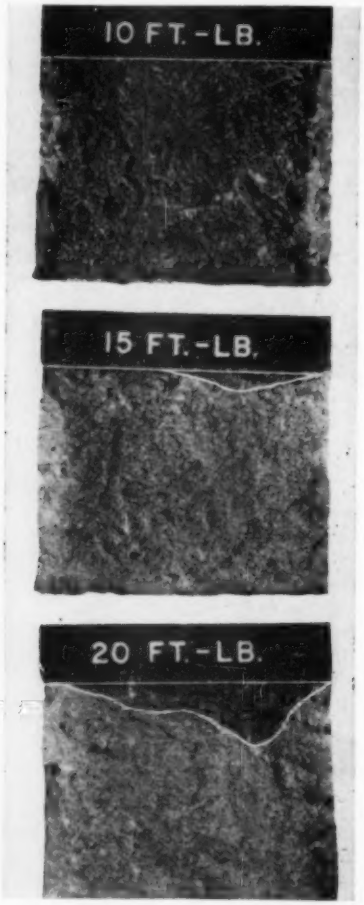


Fig. 13 Crack initiation as obtained by low-blow testing

Because of difficulty in photographing the stained crack, a line has been drawn showing the bottom of the Charpy-V notch and outlining the crack as initiated by the respective low-blow energies.

Table 4
15 Ft-Lb Transition Temperature for Ti-6% Al-4% V Heat-Affected Zone*

Heat-affected zone peak temperatures (°F)	*Transition temperatures (°C)*
1200	−80
1400	−10
1600	−30
1800	−80
2000	−80
2200	−60
2400	−40

* Transition temperature of as-received base metal −70°C.

The variation in toughness between individual heat-affected structures, as shown in the above table by transition temperatures ranging from −10 to −80° C, indicates that the most notch sensitive of the structures occurs at a point in the heat-affected zone corresponding to a peak temperature of approximately 1400° F. The WAL composite specimen, providing an integration of the variable toughness of the heat-affected structures, indicated 15 ft-lb transition temperatures of −40 to −60° C (16 and 12 ipm-arc travel speed).

Low Blow Testing

A technique has been developed at the Watertown Arsenal Laboratories for determining the site of first separa-

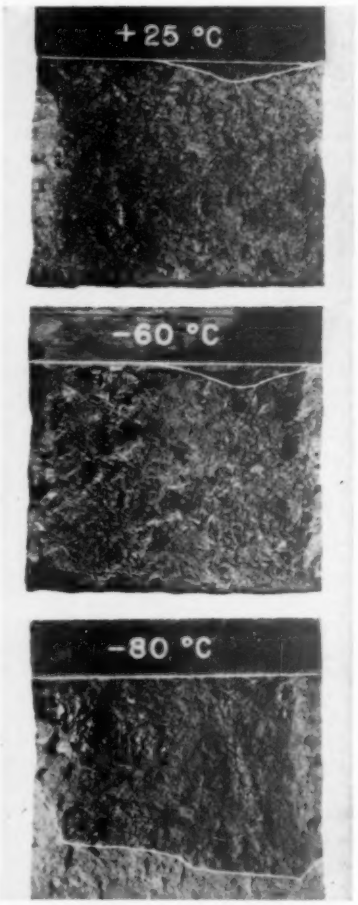


Fig. 14 Effect of temperature on extent and location of the initiating crack

A 15 ft-lb low blow delivered over a range of temperatures down to −60° C resulted in approximately the same extent and location of cracking as at room temperature. At −80° and −100° C (not shown) the 15 ft-lb initiating crack nearly fractured the test specimen and the front of the crack was relatively flat, although still leading in the heat-affected base metal side of the test specimen.

tion in the composite fracture surface (see Fig. 11 of Ref. 6). This method consists of delivering low-energy blows in the range of 5 to 30 ft-lb by releasing the pendulum of a standard impact testing machine from a calculated intermediate height. After the initial low-energy blow, the fracture surface produced by cracking is stained* and a full blow of the impact-machine pendulum is delivered to fracture the test specimen. By this technique the minimum energy required to produce perceptible cracking in the Ti – 6% Al –4% V composite specimen was found to be approximately 15 ft-lb at room temperature (see Fig. 13). As would be predicted from a consideration of the relative positions of deformation-temperature transition curves of Fig. 12, cracking consistently initiated in the heat-affected base metal. Moreover, from Fig. 13 it is apparent that crack initiation occurred at a point considerably removed from the fusion line of the weld deposit. This observation is consistent with the findings of Rensselaer Polytechnic Institute (see Table 4).

* In titanium, the crack fracture surface was readily stained by placing the specimens in a furnace at 1450° F and holding for 15 min. This method has the disadvantage of introducing an aging variable, making the energy absorbed in the final blow meaningless. The method of crack detection currently in use employs India ink containing a wetting agent.

Additional tests were made to determine the effect of temperature on the extent and location of the initial cracking produced by a 15 ft-lb low blow. A series of composite test specimens was delivered the 15 ft-lb low blow over a temperature range from +25 to −120° C. The specimens delivered a 15 ft-lb blow at −120° C fractured, indicating that at this temperature the initiating crack propagated freely under action of the elastic-stress energy developed by the low blow. The specimens which did not fracture under the initial low blow were then stained and fractured by a second full blow of the pendulum. Examination of the staining in the fracture surfaces (Fig. 14) showed that at temperatures down to −60° C the initial cracking was approximately to the same extent and in the same location as at room temperature. At −80 and −100° C the material appeared to have lost much of its resistance to crack propagation in both the heat-affected base metal and the deposited weld metal. The cracking, nevertheless, was leading in the heat-affected zone.

Conclusions

Based upon findings obtained from weldments made in a single heat of material, it was concluded that (1) Ti – 6% Al – 4% V welded with the inert-gas-shielded tungsten-arc process with matching filler and base metal will have approximately 100% tensile joint efficiency at an ultimate tensile strength of 150,000 psi and 10 ft-lb of V-notch Charpy-impact energy at −40° C and (2) Ti – 6% Al – 4% V welded with the inert-gas-shielded consumable-electrode process will have considerably greater notch toughness in the heat-affected zone than other commercially available alpha-beta titanium alloys.

References

1. Faulkner, G. E., Gable, G. B., and Voldrich, C. B., "Effects of Alloying Elements in Welds in Titanium," THE WELDING JOURNAL, **32** (10), Research Suppl., 480-s to 497-s (1953); **34** (6), (1955).
2. Nippes, E. F., and Savage, W. F., "Development of a Specimen Simulating Weld Heat-Affected Zones," *Ibid.*, **28** (11), Research Suppl., 534-s (1949).
3. Hartbower, C. E., and Daley, D. M., Jr., "Alloy Weld Deposits in 'Unalloyed' Titanium Base Metal," WAL Rept. No. 401/216, *Ibid.*, **33** (7) 311-s to 326-s and (8) 401-s to 414-s (1954).
4. Daley, D. M., Jr., and Hartbower, C. E., "Notch Toughness of Weld Deposits in Commercial Titanium Alloys," WAL Rept. No. 401/221, *Ibid.*, **35** (9), 447-s to 456-s (1956).
5. Faulkner, G. E., "The Effects of Alloying Elements on Welds in Titanium—Part II," *Ibid.*, **34** (6), Research Suppl., 295-s (1955).
6. Hatch, W. P., and Hartbower, C. E., "Charpy Impact Testing Weld Metal and Heat-Affected Zone Simultaneously," WAL Rept. No. 401/220, *Ibid.*, **35** (3), 120-s to 126-s (1956).
7. Hartbower, C. E., "Poisson Effect in the Charpy Test," *ASTM Proc.*, **54**, 929 (1954).
8. Nippes, E. F., and Gerken, J. M., "Notch Sensitivity of the Weld Heat-Affected Zones of a 6% Al – 4% Titanium," Final Rept., Contract DA-30-115-ORD-(P)-642, WAL Rept. No. 11/2 86-7, October 1955.

RESEARCH NEWS

Results of U. S. Government Research Available to Science and Industry

Nonclassified results of the growing volume of Government-financed scientific research, estimated at a $2.7 billion level for the current fiscal year, are being turned over to American science and industry in increasing quantity through the Office of Technical Services, U. S. Department of Commerce, according to John C. Green, OTS Director.

Government research represents about half of the total R&D work of the nation, and many of the developments achieved through this research have immediate application in industrial plants and scientific laboratories. For this reason, OTS, operating under a special law passed by Congress in 1950, is responsible for collecting research reports from the Army, Navy, Air Force, Atomic Energy Commission and other agencies, reproducing them, and selling them to the public at the cost of reproduction and handling. Last year approximately 182,000 printed or microfilmed copies of such reports were sold.

In addition to research reports, OTS also publishes abstracts of Government-owned patents that are now free for use by private firms on a nonexclusive basis.

To keep science and industry advised of new material released through OTS, the office issues news releases to the trade, business and technical press and publishes two monthly periodicals. *U. S. Government Research Reports*, a bibliography, describes 300 to 600 new reports in each issue. *Technical Reports Newsletter* reviews 15 to 20 of the most widely usable reports collected by OTS each month. These publications may be ordered from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at $6 a year for the USGRR and $1 a year for *Technical Reports Newsletter*. In addition, subject catalogs have been prepared in some fields, and a list of these *Catalogs of Technical Reports* is available from OTS on request.

The quantity of material available from OTS has increased rapidly in recent years, both because of expanded acquisition efforts and because of the increasing volume of Government research to meet new technical requirements for the nation's welfare. The National Science Foundation recently estimated that expenditures for Federal research increased from $2.3 billion in 1955 to $2.4 billion in 1956 and $2.7 billion in 1957.

STUDIES OF UPSET VARIABLES IN THE FLASH WELDING OF STEELS

Influence of temperature gradient prior to upset, upset current density and composition of material on the upset behavior determined for three steels of differing elevated-temperature strength

BY E. F. NIPPES, W. F. SAVAGE, G. GROTKE AND S. M. ROBELOTTO

ABSTRACT. Flash welds were prepared in three steels of differing elevated-temperature strength, employing two rates of platen acceleration and controlled amounts of upset current. The influence of the temperature gradient prior to upset, the upset current density and the composition of the material on the upset behavior was determined. It was noted that the influence of the temperature distribution at the instant of upset persists even when upset currents of large magnitude are employed.

Welds made under the above conditions were bend tested to initial cracking, to constant bend angle and, if possible, to destruction in order to relate the upset variables and weld quality. Significant differences were noted in the three steels in the nature and severity of cracking, crack location and in the incidence of flat-spots and weld-line cracks.

Macrographs of similar welds are included showing the effect of variations in upset distance and platen acceleration on the orientation of the fiber structure in the vicinity of the joint. An etching technique was developed permitting detection of those flat-spots which intersect the surface of the specimen and an hypothesis of the formation of flat-spots is presented, based, in part, upon metallographic studies and microhardness measurements.

In addition, a preliminary investigation of the nature of flashing was attempted employing high-speed motion pictures of flashing action and oscillographic measurement of current and voltage. Oscillograms of primary voltage, secondary voltage and primary current during flashing are presented and discussed.

Introduction

The number of variables involved in the flash welding process make the selection of optimum welding conditions extremely difficult. Over a period of years, research[1, 2–5] has been conducted at Rensselaer Polytechnic Institute in an effort to determine the effect of the independent variables on the process and to study the interrelation between variables. To date, the influence of the flashing variables on the temperature distribution at the instant of upset has been studied extensively, and, as a result, methods for the prediction and control of the temperature distribution at upset have been established.[6] In addition, the effect of welding variables on the cooling rates experienced in flash welds was investigated, and the results were correlated with the microstructure and properties produced in welding plain carbon and low-alloy steels.

The present program draws heavily on the knowledge accumulated in prior research and constitutes an investigation of the effect of upset variables on weld performance.

E. F. Nippes, W. F. Savage, G. Grotke and S. M. Robelotto are associated with Department of Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.

Object and Scope

The objectives of this investigation were threefold:

1. To determine the effects of the temperature distribution at the instant of upset and the upset current density on the upsetting action.
2. To study the effect of upset distance on the microstructure and mechanical properties of flash welds.
3. To investigate, by high-speed photographic and oscillographic means, the influence of changes in the secondary reactance of the welding transformer on the flashing behavior.

Material

Experimental data for this report were obtained from welds in $^3/_8$-x 2- x 6-in. specimens. The steels employed, which were supplied in the pickled-and-oiled condition, are listed, together with their compositions, in Table 1. No special end preparation was used other than cutting to length with an abrasive cutoff wheel, and removing the burr by a light grinding operation. The steels were degreased prior to use, and excessive scale was removed by abrasive belt grinding.

The 4130 steel showed severe decarburization of at least one surface and, in addition, exhibited a prominent banded structure. The 1020 and 4340 steels were, for the most part, free of these defects.

Equipment

Welding Equipment

This study was conducted using a 300-kva flash welder modified in this laboratory as described in previous reports.[1, 2] Power for welding was obtained from a recently installed motor-generator unit consisting of a 200-hp, 4160-v, 3-phase, synchronous motor, driving a 500-kva single-phase alternator of extremely low transient reactance. The output of the welding supply is amplidyne controlled, and is continuously variable over the range 100–600 v. The higher capacity and greatly improved voltage regulation provided by this supply has more than doubled the demand current available for welding research, and, has made

Table 1—Composition of the Steels Employed for Weld Specimens

Steel	*Heat No.*	% *C*	*P*	*S*	*Si*	*Mn*	*Cr*	*Mo*	*Ni*
AISI 1020	(Nominal)	0.18–0.23	0.04*	0.05*	..	0.30–0.60	..	..	..
AISI 4130	H34362A	0.295	0.014	0.018	0.25	0.53	0.95	0.21	..
AISI 4340	H34308A	0.385	0.013	0.022	0.23	0.78	0.80	0.25	1.74

* Maximum.

Table 2—Calculated Stable Temperature Distributions at the Instant of Upset for the Platen Accelerations Employed*

Platen acceleration, ips²	Temperature, ° F, at indicated distance, in. 0.05 in.	0.10 in.	0.15 in.	0.25 in.	0.35 in.
0.05	1525	1150	925	650	425
0.02	2100	1625	1175	775	550

* Obtained by a method described in previous reports.[3, 4]

possible studies which could not be attempted previously owing to the inadequate power supply.

Instrumentation

All data on the welding variables employed in preparation of weld specimens were obtained with the aid of an 18-channel, recording oscillograph. Oscillograms prepared in the course of the investigation of transformer reactance were made with an oscillograph. The high-speed photographs of flashing action taken during this latter study were obtained using a high-speed camera.

Upset Current Studies

Welding Procedure

All weld specimens for this investigation were prepared from $^3/_8$ - x 2- x 6-in. specimens, using an initial clamping distance of 2.0 in. and a total burn-off of 0.55 in. Two rates of platen acceleration were selected for study, 0.05 and 0.02 ips²: the first, to provide a relatively steep temperature distribution and the second, to provide a more gradual temperature distribution. With each value of flashing acceleration, four duplicate welds were prepared using each of the following upset current densities, 0, 4000, 10,000, 18,000, 28,000 and 45,000 amp/in.². The magnitude of the upset current was determined from oscillographic records of the welding transformer primary current by multiplying the observed primary current by the welding transformer turns ratio. Secondary voltage during flashing was 11.3 v. The upsetting force was the maximum available with the present machine, a force of the order of 25,000 lb, and upset stops were not employed.

The stable temperature distribution existing at the instant of upset has been summarized in Table 2 for each of the flashing conditions used. The temperature distribution data were obtained by the method described in previous reports[3, 4] summarizing the influence of flashing variables on the temperature distribution at the instant of upset.

A complete tabulation of the welding conditions employed for each of the 144 flash welds prepared for this study may be found in Appendix II. The upset current duration, upset current density, upset force and the total upset distance associated with welds prepared at platen acceleration rates of

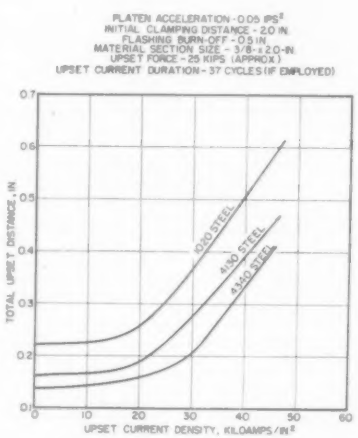

PLATEN ACCELERATION - 0.05 IPS²
INITIAL CLAMPING DISTANCE - 2.0 IN.
FLASHING BURN-OFF - 0.5 IN.
MATERIAL SECTION SIZE - 3/8 x 2.0 IN.
UPSET FORCE - 25 KIPS (APPROX.)
UPSET CURRENT DURATION - 37 CYCLES (IF EMPLOYED)
TOTAL UPSET DISTANCE, IN.
UPSET CURRENT DENSITY, KILOAMPS/IN²
1020 STEEL
4130 STEEL
4340 STEEL

Fig. 1 Total upset distance as a function of upset current density—Platen acceleration, 0.05 ips²

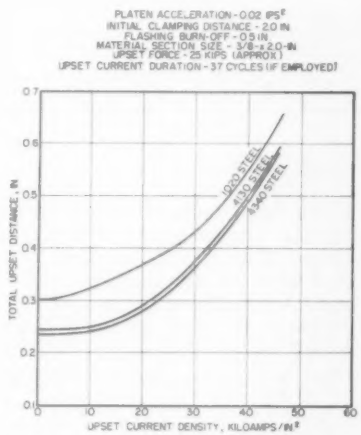

PLATEN ACCELERATION - 0.02 IPS²
INITIAL CLAMPING DISTANCE - 2.0 IN.
FLASHING BURN-OFF - 0.5 IN.
MATERIAL SECTION SIZE - 3/8 x 2.0 IN.
UPSET FORCE - 25 KIPS (APPROX.)
UPSET CURRENT DURATION - 37 CYCLES (IF EMPLOYED)
TOTAL UPSET DISTANCE, IN.
UPSET CURRENT DENSITY, KILOAMPS/IN²
1020 STEEL
4130 STEEL
4340 STEEL

Fig. 2 Total upset distance as a function of upset current density—Platen acceleration, 0.02 ips²

Table 3—Summary of Flash Welding Conditions Used in the Study of the Effect of Upset Current Density on Upset Distance

Platen acceleration, 0.05 ips². Section size, $^3/_8$ x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset current duration, 37 cycles (if employed)

Group	Weld No.	Steel	Upset current phase setting, %	Avg upset current duration, sec	Avg upset current density, amp/in.²	Avg upset force, kips	Avg total upset distance, in.
A	1–4	1020	0	...	...	24.9	0.24
B	5–8	1020	20	0.62	4,300	24.2	0.21
C	9–12	1020	40	0.62	10,600	23.9	0.23
D	13–16	1020	60	0.63	18,600	23.9	0.25
E	17–20	1020	80	0.61	28,800	24.5	0.37
F	21–24	1020	100	0.63	45,900	23.9	0.60
G	25–28	4130	0	...	...	24.5	0.16
H	29–32	4130	20	0.62	4,200	25.3	0.17
I	33–36	4130	40	0.62	10,100	24.8	0.16
J	37–40	4130	60	0.61	17,600	24.5	0.18
K	41–44	4130	80	0.62	28,400	24.5	0.25
L	45–48	4130	100	0.63	45,100	24.3	0.46
M	49–52	4340	0	...	...	25.1	0.14
N	53–56	4340	20	0.61	4,100	25.5	0.14
O	57–60	4340	40	0.61	10,300	25.5	0.14
P	61–64	4340	60	0.61	18,100	25.3	0.16
Q	65–68	4340	80	0.62	27,800	24.7	0.19
R	69–72	4340	100	0.61	43,700	24.3	0.39

Table 4—Summary of Flash Welding Conditions Used in the Study of the Effect of Upset Current Density on Upset Distance

Platen acceleration, 0.02 ips². Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset current duration 37 cycles (if employed)

Group	Weld No.	Steel	Upset current phase setting, %	Avg upset current duration, sec	Avg upset current, amp/in.²	Avg upset force, kips	Avg total upset distance, in.
AA	73–76	1020	0	...	...	25.4	0.31
BB	77–80	1020	20	0.61	4,200	24.4	0.30
CC	81–84	1020	40	0.61	10,600	24.0	0.32
DD	85–88	1020	60	0.61	18,800	23.9	0.37
EE	89–92	1020	80	0.61	29,000	23.8	0.42
FF	93–96	1020	100	0.61	45,500	24.1	0.65
GG	97–100	4130	0	...	...	25.1	0.25
HH	101–104	4130	20	0.60	4,000	24.9	0.25
II	105–108	4130	40	0.60	10,000	25.1	0.24
JJ	109–112	4130	60	0.61	18,300	25.0	0.28
KK	113–116	4130	80	0.62	28,000	24.8	0.36
LL	117–120	4130	100	0.62	44,600	24.6	0.57
MM	121–124	4340	0	...	...	26.4	0.23
NN	125–128	4340	20	0.61	3,900	26.5	0.24
OO	129–132	4340	40	0.61	9,900	26.4	0.24
PP	133–136	4340	60	0.61	18,000	26.3	0.27
QQ	137–140	4340	80	0.61	27,600	26.1	0.34
RR	141–144	4340	100	0.62	44,300	25.4	0.56

0.05 and 0.02 ips² are presented. Since only minor variations in the welding variables may be noted within each group of four duplicate welds, the average value of each variable, obtained from all four duplicate welds, was taken as representative of the group. These average values of the welding variables for each of the 18 groups of welds prepared at a platen acceleration rate of 0.05 ips² are summarized in Table 3. Similar average data are shown in Table 4 for the 18 groups of welds prepared at the slower acceleration rate of 0.02 ips².

Results of Upset Current Studies

Curves illustrating the influence of upset current on the total upset distance are plotted in Figs. 1 and 2 for welds flashed at platen acceleration rates of 0.05 and 0.02 ips², respectively. In both Figs. 1 and 2, the effects of superior elevated-temperature strength of the alloyed steels are evident. In each group of curves, the 4340 grade, owing to the higher alloy content, shows the least upset travel at any level of applied upset current, the plain-carbon steel is the most readily upset, and the 4130 grade, being intermediate in composition, occupies an intermediate position.

The acceleration rates and initial clamping distance were chosen to permit the preparation of welds having insufficient upset when upset current was not employed, and large upset distances when upset current densities of the order of 45,000 amp/in.² were used. Inspection of Fig. 1 reveals that the available upset force of 25,000 lb was sufficient to produce a total upset of only 0.14 in. in AISI 4340 steel, 0.16 in. in AISI 4130 and 0.22 in. in the AISI 1020 steel without application of upset current. With an upset current density of 45,000 amp/in.² of 37 cycles duration, however, the same force produced total upset distances of 0.40, 0.45 and 0.58 in., for the 4340, 4130 and 1020 steels, respectively. It will be noted from Fig. 1 that only a minor increase in upset distance resulted until an upset current density of about 25,000 amps/in.² was employed.

Inspection of Fig. 2, which shows the effect of upset current density on upset distance for welds prepared at the slower acceleration rate of 0.02 ips², indicates that the temperature gradient existing in the specimen just prior to upset influences the upset characteristics. The more gradual temperature gradient associated with welds flashed

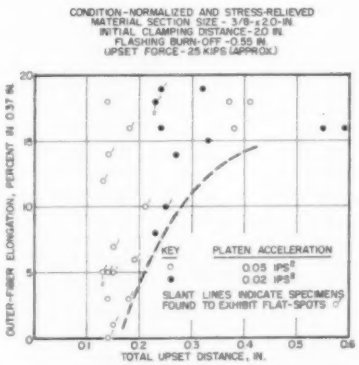

CONDITION - NORMALIZED AND STRESS-RELIEVED
MATERIAL SECTION SIZE - 3/8 x 2.0 IN.
INITIAL CLAMPING DISTANCE - 2.0 IN.
FLASHING BURN-OFF - 0.55 IN.
UPSET FORCE - 25 KIPS (APPROX.)
OUTER-FIBER ELONGATION, PERCENT IN 0.37 IN.
TOTAL UPSET DISTANCE, IN.
KEY
PLATEN ACCELERATION
0.05 IPS²
0.02 IPS²
SLANT LINES INDICATE SPECIMENS FOUND TO EXHIBIT FLAT-SPOTS

Fig. 3 Elongation at initial cracking as a function of total upset distance—AISI 4340 steel

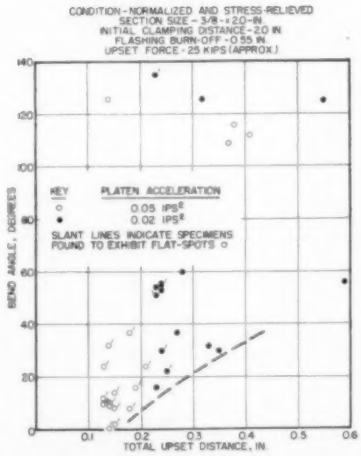

CONDITION - NORMALIZED AND STRESS-RELIEVED
SECTION SIZE - 3/8 x 2.0 IN.
INITIAL CLAMPING DISTANCE - 2.0 IN.
FLASHING BURN-OFF - 0.55 IN.
UPSET FORCE - 25 KIPS (APPROX.)
BEND ANGLE, DEGREES
TOTAL UPSET DISTANCE, IN.
KEY
PLATEN ACCELERATION
0.05 IPS²
0.02 IPS²
SLANT LINES INDICATE SPECIMENS FOUND TO EXHIBIT FLAT-SPOTS

Fig. 4 Bend angle at initial cracking as a function of total upset distance—AISI 4340 steel

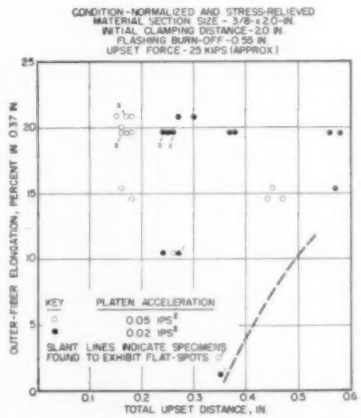

CONDITION - NORMALIZED AND STRESS-RELIEVED
MATERIAL SECTION SIZE - 3/8 x 2.0 IN.
INITIAL CLAMPING DISTANCE - 2.0 IN.
FLASHING BURN-OFF - 0.55 IN.
UPSET FORCE - 25 KIPS (APPROX.)
OUTER-FIBER ELONGATION, PERCENT IN 0.37 IN.
TOTAL UPSET DISTANCE, IN.
KEY
PLATEN ACCELERATION
0.05 IPS²
0.02 IPS²
SLANT LINES INDICATE SPECIMENS FOUND TO EXHIBIT FLAT-SPOTS

Fig. 5 Elongation at initial cracking as a function of total upset distance—AISI 4130 steel

at the slower acceleration rate results in an increase in upset travel for all values of upset current. For example, the total upset distance for 4340 steel, flashed at an acceleration of 0.05 ips² and welded without the use of upset current was seen, in Fig. 1, to be 0.14 in. By comparison, Fig. 2 reveals that the more gradual temperature gradient produced by a platen acceleration of 0.02 ips² permitted a total upset of 0.23 in.

The following comparison indicates that the influence of the temperature distribution at the instant of upset persists even when large magnitude upset currents are employed. Inspection of the curve in Fig. 1 for welds in 4340 steel reveals that with a platen acceleration of 0.05 ips² and an upset current density of 45,000 amps/in.², the 25,000-lb upset force was sufficient to produce an increase in the total upset distance of 0.40 in. However,

Table 5—Results of Guided-Bend Testing to Initial Failure (4340 Steel)

Platen acceleration, 0.05 ips². 4340 steel, normalized and stress relieved. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	Weld No.	Upset current phase setting, %	Upset current density, amp/in.²	Total upset distance, in.	Outer fiber elongation, % in 0.37 in.	Bend angle, deg	Location and No. of cracks			Crack length, in.‡
							HAZ*	WL†	Edge	
M	49	0	...	0.14	18	126	1	..	..	...
	50	0	...	0.15	1	2	..	1	..	3/8
	51	0	...	0.14	3	9	..	3	..	(1) 1/4, (1) 3/32
N	54	20	4,000	0.14	0	1	..	1	..	3/8
	55	20	4,200	0.13	12	24	..	1	..	1/4
	56	20	4,000	0.13	5	10	..	2	..	(1) 3/8
O	57	40	10,300	0.13	5	12	..	1	..	1/8
	58	40	10,300	0.14	5	32	..	1	WL	1/2 edge, 1/8 WL
	59	40	10,200	0.14	14	10	..	1	..	1/8
P	61	60	18,300	0.18	3	8	..	..	WL	3/8
	63	60	17,900	0.15	7	14	..	1	..	1/4
	64	60	18,000	0.15	5	8	..	..	WL	1 1/4
Q	66	80	27,700	0.18	16	37	..	2	..	1/16 and 1/4
	67	80	28,000	0.21	10	24	..	1	..	3/8
	68	80	28,000	0.19	6	16	..	1	..	1/8
R	69	100	43,600	0.38	16	116	1	..	..	
	70	100	44,000	0.37	18	109	None	..	..	
	72	100	44,200	0.41	18	112	1	1	..	

* HAZ, Heat-affected zone.
† WL, Weld line.
‡ Any crack not specifically described in this column was of pinhole size.

Table 6—Results of Guided-Bend Testing to Initial Failure (4340 Steel)

Platen acceleration, 0.02 ips². 4340 steel, normalized and stress relieved. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	Weld No.	Upset current phase setting, %	Upset current density, amp/in.²	Total upset distance, in.	Outer-fiber elongation, % in 0.37 in.	Bend angle, deg	Location and No. of cracks			Crack length, in.‡
							HAZ*	WL†	Edge	
MM	122	0	...	0.24	§	30	3	..	WL	1 edge
	123	0	...	0.22	Specimen lost		..	..	..	...
	124	0	...	0.24	16	56	1	1	..	...
NN	125	20	3,900	0.24	§	53	2	2	..	(1) HAZ 1/8
	126	20	3,900	0.24	19	55	1	..	..	1/8
	128	20	3,900	0.23	8	16	..	1	..	Full width
OO	129	40	10,100	0.23	§	135	..	3	..	...
	130	40	10,100	0.23	18	51	..	1	..	...
	131	40	9,400	0.23	18	54	2	..	..	...
PP	133	60	17,400	0.25	10	22	..	1	..	3/16
	135	60	18,100	0.28	§	60	1	1	..	...
	136	60	18,800	0.27	14	37	..	1	..	3/16
QQ	137	80	27,700	0.33	15	37	..	2	..	(1) 1/16
	138	80	27,600	0.32	19	126	1	..	..	...
	139	80	27,200	0.35	§	30	..	1	..	3/8
RR	141	100	45,300	0.59	16	56	..	..	WL	3/4
	142	100	43,900	0.55	Not stress relieved		..	..	..	...
	144	100	44,000	0.55	16	129	1	..	..	...

* HAZ, Heat-affected zone.
† WL, Weld line.
‡ Any crack not specifically described in this column was of pinhole size.
§ Complete data not available.

when the acceleration rate during flashing is reduced to 0.02 ips², Fig. 2 reveals that a current density of 45,000 amps/in.² resulted in a total upset of 0.57 in. with AISI 4340 grade. A corresponding relationship may be observed for the other two steels.

Bend Testing of Flash Welds

Preparation and Procedure

From each group of four duplicate welds, prepared at a particular condition of acceleration and upset current density given in Tables 3 and 4, three welds were selected for bend testing. The welds selected were those of the group which exhibited the best alignment, if a difference in alignment was apparent. The remaining weld of each group was set aside for subsequent metallographic examination. After the flash was removed by rough grinding or machining, the welds in 4340 or 4130 steel were heated 20 min at 1500 and 1560° F, respectively, air-cooled and then stress-relieved for 30 min at 1100° F. The plain-carbon steel was tested in the as-welded condition. Each specimen was abrasive-belt ground in the region of the weld to remove heat-treatment scale and surface defects. It was found, after etching to reveal the weld line, that the maximum width of the heat-affected zone was slightly less than $^3/_8$ in. Therefore, gage marks 0.37 in. apart and centered about the weld line were scribed on each specimen. A gage length of 1.0 in. was also employed on some specimens early in this investigation; however, the elongation values obtained when the larger gage length was used were found to be erratic, and the practice was discontinued.

Bend testing of the welds made in 4340 steel was performed in a guided-bend-test fixture. This standard fixture did not furnish a severe enough test for the more ductile 4130 and 1020 steels, and, therefore, the standard $^3/_4$ -in. radius upper ram was replaced with one of $^1/_2$-in. radius.

In order to obtain the maximum amount of information on the properties of the available welds, the following procedure was employed:

1. *Bending to Initial Failure.* The specimens were bent until the first crack, other than an edge crack, had propagated to $^1/_{16}$ in. in length, or until cracking of the pinhole type was extensive. Edge cracking, if it occurred, always appeared at the weld line early in the test, and either propagated rapidly across the bar or terminated shortly in a diagonal, shear-type tear. In the cases where edge cracking was encountered, testing was terminated when the edge crack had grown to a length of approximately $^1/_{\text{?}}$-in. Following this initial testing operation the percentage elongation in the outer fibers was determined, and the type of failure, location of failure and bend angle were recorded.

2. *Full-Bend Testing.* All specimens were then replaced in the bending jig and bent to an angle of about 135 deg, this angle being the maximum permitted by the design of the bend-test fixture. The total crack length, location and elongation were determined, and, in cases where fracture occurred, the location and type of fracture and the presence of flat-spots were noted.

3. *U-Bend Test.* Those specimens which remained unbroken were further U bent and compressed to a total height of 1.5-in. in order to promote fracture at the weld line and permit examination of this surface.

Bend Test Results for 4340 Steel

Bending to Initial Failure

Tables 5 and 6 summarize the results obtained by bend testing the welds in 4340 steel to the initial failure point. These tables show the elongation in the outer fiber, the bend angle and the location and severity of cracking. The data of Table 5 are from welds prepared at a platen acceleration of 0.05 ips², and those of Table 6 are from welds made with the slower 0.02 ips² acceleration rate. The normalized and drawn 4340 steel, having a high hardness level, exhibited such a rapid rate of crack propagation that it was often impossible to stop the bending at the time when the initial crack length was the desired $^1/_{16}$ in. This difficulty resulted in abnormally high initial-crack-length values as may be seen in Tables 5 and 6, but was not encountered when testing the more ductile 4130 and 1020 steels.

Examination of Tables 5 and 6 shows that cracking in AISI 4340 generally

Table 7—Results of Full Guided-Bend Tests (4340 Steel)

Platen acceleration, 0.05 ips². 4340 steel, normalized and stress relieved. Section size, $^3/_8$ x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	Weld No.	Upset current phase setting, %	Total upset distance, in.	Crack location and No.* HAZ†	Crack location and No.* WL‡	Comments	Flat spots
M	49	0	0.14	None		.....	.....
	50§	0	0.15	..	..	Broken WL (50% ductile)	1 small
	51	0	0.14	..	..	Broken WL (10% ductile)	...
N	54§	20	0.14	..	..	Broken WL (10% ductile)	2 small
	55§	20	0.13	..	..	Broken WL (50% ductile)	1 large
	56	20	0.13	..	..	Broken WL (50% ductile)	1 small
O	57	40	0.13	..	..	Broken mostly HAZ (100% ductile)	1 large
	58§	40	0.14	..	..	Broken WL (25% ductile)	2 large
	59	40	0.14	..	..	Broken mostly WL (50% ductile)	1 small
P	61	60	0.18	..	..	Broken WL (50% ductile)	1 large
	63	60	0.15	..	..	Broken WL (50% ductile)	2 large
	64	60	0.15	..	..	Broken WL (0% ductile)	1 small
Q	66	80	0.18	..	..	Broken WL (50% ductile)	2 large
	67	80	0.21	..	..	Broken WL (10% ductile)	1 large, 1 small
	68	80	0.19	..	..	Broken mostly HAZ (50% ductile)	1 small
R	69	100	0.38	None		.....	...
	70	100	0.37	..	1	$^1/_{16}$ in.	...
	72	100	0.41	None		.....	...

* Pinhole cracks have not been included in this table.
† HAZ, Heat-affected zone.
‡ WL, Weld line.
§ Indicates specimens which showed heat-treatment cracks.

Table 8—Results of Full Guided-Bend Tests (4340 Steel)

Platen acceleration, 0.02 ips². 4340 steel, normalized and stress relieved. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	Weld. No.	Upset current phase setting, %	Total upset distance, in.	Crack location and No.* HAZ†	Crack location and No.* WL‡	Comments	Flat spots
MM	122	0	0.24	..	..	Broken WL (25% ductile)	2 large
	123	0	0.22	..	..	Specimen lost	....
	124	0	0.24	1	1	Both 1/8 in.	....
NN	125	20	0.24	2	2	Both WL 1/32 in., HAZ 1/4 and 1/8 in.	....
	126	20	0.24	..	..	Broken mostly WL (100% ductile)	1 small
	128	20	0.23	..	..	Broken WL (0% ductile)	....
OO	129	40	0.23	1	..	1/16 in.	Scattered small
	130	40	0.23	..	..	Broken HAZ (75% ductile)	1 small
	131	40	0.23	1	..	1/4 in.	....
PP	133	60	0.25	..	..	Broken mostly WL (25% ductile)	Scattered small
	135	60	0.28	..	2	1/16 and 1/8 in.	....
	136	60	0.27	..	..	Broken mostly HAZ (25% ductile)	....
QQ	137	80	0.33	..	..	Broken mostly WL (25% ductile)	....
	138	80	0.32	None			....
	139	80	0.35	..	..	Broken HAZ (75% ductile)	....
RR	141	100	0.59	..	..	Broken WL (100% ductile)	....
	142	100	0.55	..	..	Not stress relieved	....
	144	100	0.55	None			....

* Pinhole cracks have not been included in this table.
† HAZ, Heat-affected zone.
‡ WL, Weld line.

occurred at the weld line when the total upset distance was less than about 0.20 in. However, when the upset travel exceeded 0.20 in., cracking at other locations within the heat-affected zone may be observed. It should be noted that no failures outside the weld-heat-affected zone were found in this steel in this test. In Table 5 it may be seen that those welds of the final group, prepared with an average upset current density of 44,300 amp/in.², exhibited much more resistance to major cracking than did welds in which lesser upset distance was obtained. However, the results of increased upset distance on ductility are best illustrated in the plots of Figs. 3 and 4. These plots of outer-fiber elongation prior to initial failure vs. total upset distance were prepared from the data of Tables 5 and 6. In each of these figures the points obtained from specimens later found to contain flat spots are identified.

In Fig. 3, showing the elongation at initial failure as a function of upset distance for a range of upset distances from 0.13 to 0.59 in., it is apparent that increased upset travel results in increased ductility prior to the occurrence of the initial failure. Several elongation values of 5% or less were obtained when the total upset distance employed was of the order of 0.15 in., but, when the upset distances were 0.30 in., or greater, it may be seen that the lowest elongation value obtained was 15%. Elongation values determined for welds which had lesser upset distances are erratic. For example, at or near a total upset distance of 0.14 in. elongation values ranging from 0 to 18% were obtained.

As indicated in Fig. 3, flat-spots were not found to occur in any weld in 4340 steel which was upset more than 0.25 in. Furthermore, it may be seen that nearly all of the specimens which exhibited low elongation contained these flaws. No differentiation was made in the flat-spot identifications between those flat-spot formations which were judged to be severe and those which were of a minor nature. However, only two specimens in which the flat-spots were considered "large" were found to show elongation values greater than 8%, and no large flat-spots were found in specimens which were upset a distance greater than 0.24 in.

Data presented in Fig. 4, showing the variation in the angle of bend at initial failure for the range of upsets investigated, indicates trends similar to those observed in Fig. 3. In this figure, however, there appears to be a trend for a continuous increase in weld quality as the total upset distance is increased beyond the 0.15 in. value. Again, flat spots are associated with welds having poor ductility, and considerable scatter may be seen in the bend angle data in the region of the lower upset distances. It is of interest to note, at this point, that unwelded samples of 4340 steel, of the same dimensions, and heat treated in the same manner, yielded consistent elongations of 22–24% and showed no indication of cracking when bent to angles of 140–160 deg.

Full Guided-Bend Tests of 4340 Steel

Results of the full-bend tests on specimens of 4340 steel may be found in Table 7 for welds prepared at the more rapid rate of platen acceleration of 0.05 ips². It will be noted from the large number of samples which broke before bending could be completed that this test procedure is not suited for 4340. None the less, many items of significance may be observed in these data.

Of the 18 specimens of groups M through R only four specimens were able to withstand the full-bend test, and all of these four welds were of markedly superior quality. One weld of group M (No. 49), which had only 0.14 in. of upset travel but which was free of flat-spots and heat-treatment cracks, and two welds of group R (Nos. 69 and 72), having 0.38 and 0.41 in. of upset travel, respectively, were either crack-free or showed cracking of such a minor nature that the crack length was not determined. Significantly, the remaining weld of Group R (No. 70), having 0.37 in. of upset, showed only a 1/16-in. weld-line crack. Again, as noted in Tables 5 and 6, failures in this material were predominantly at the weld line. The flat-spot data shown in Table 7 has been discussed, to some extent, in the previous section. It may be seen, however,

that there appears to be no correlation between the upset distance and the size of flat-spots for the range of upset 0.13–0.21 in. An area equal to or greater than that of a $^1/_4$-in. diameter circle was taken as the criteria for a "large" flat spot. No correlation was found between the ductility of the fracture and the amount of upset travel for welds of groups M-Q.

Four welds, all having upset distances of less than 0.16 in., showed evidence of having cracked prior to or during heat treatment. It would appear that it is possible to avoid these flaws by relatively slight increases in upset, since welds prepared at the slower acceleration rate of 0.02 ips², for which the data are shown in Table 8, did not exhibit a single heat-treatment crack. These welds made at the slower platen acceleration rate had a minimum upset distance of 0.23 in.

From Table 8, it may be seen that more of the welds flashed at 0.02 in./sec² were able to withstand full bending. This is attributed to the greater upset distances experienced by these welds as a result of the more gradual temperature gradient at the instant of upset. Furthermore, a tendency for failure to occur in the heat-affected zone can be observed, in contrast to the rarity of heat-affected-zone failure in specimens prepared at the faster rate of acceleration which were subjected to less upset action. Flat spots were not found to have occurred in any weld upset a distance greater than 0.25 in., and, when the data of Tables 7 and 8 are examined, there appears to be a trend to fewer and smaller flat-spots as the upset travel approaches 0.25 in.

U-Bend Testing of Welds in 4340 Steel

Results of the testing procedure involving U bending followed by compression to 1.5 in. head space are presented in Tables 9 and 10 for welds prepared at acceleration rates of 0.05 and 0.02 ips², respectively. The data of Table 9 show that the four welds which remained unbroken during the full-bend test were also able to resist complete fracture in this final, severe test. These specimens, however, generally showed extensive cracking in the heat-affected zone, as did the welds which were prepared at the slower acceleration rate, as shown in Table 10. It is of interest to note in these tables, that, with but one exception, complete fracture occurred in each of the 18 welds which showed any indication of flat-spots, even of a minor nature. However, it is possible to attach too much significance to these results, since, owing to the severity of the test procedure employed, fracture was induced in an additional seven welds which were found to be completely free of flat-spot indications.

Bend Test Results for 4130 Steel

Bending to Initial Failure

The outer-fiber elongation, angle of bend, location of failure and the crack length at initial failure for welds prepared at acceleration rates of 0.05 and 0.02 ips² are presented in Tables 11 and 12, respectively. The enhanced ductility of welds in the 4130 grade, compared with the previously discussed

Table 9—Results of U-Bend Testing to 1.5-In. Head Space (4340 Steel)

Platen acceleration, 0.05 ips². 4340 steel, normalized and stress relieved. Section size, $^3/_8$ x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	*Weld No.*	*Upset current phase setting, %*	*Total upset distance, in.*	*Comments*
M	49	0	0.14	Cracked (HAZ*), $1^3/_4$ in.
	50†	0	0.15	‡
	51	0	0.14	‡
N	54†	20	0.14	‡
	55†	20	0.13	‡
	56†	20	0.13	
O	57†	40	0.13	‡
	58†	40	0.14	‡
	59†	40	0.14	‡
P	61†	60	0.18	‡
	63†	60	0.15	‡
	64†	60	0.15	‡
Q	66†	80	0.18	‡
	67†	80	0.21	‡
	68†	80	0.19	‡
R	69	100	0.38	Cracked (HAZ), $^1/_2$ and $^1/_4$ in.
	70	100	0.37	Cracked (HAZ), $^1/_{16}$ in.
	72	100	0.41	Cracked (HAZ), $1^3/_4$ in.

* HAZ, Heat-affected zone.
† Indicates specimens which exhibited flat-spots.
‡ Indicates specimens broken in previous testing.
NOTE: Pinhole cracks have not been included in this table.

Table 10—Results of U-Bend Testing to 1.5-In. Head Space (4340 Steel)

Platen acceleration, 0.02 ips². 4340 steel, normalized and stress relieved. Section size, $^3/_8$ x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	*Weld No.*	*Upset current phase setting, %*	*Total upset distance, in.*	*Comments*
MM	122*	0	0.24	†
	123	0	0.22	Specimen lost
	124	0	0.24	Cracked completely (HAZ‡)
NN	125	20	0.24	Cracked $1^3/_4$ in. (mostly WL§)
	126*	20	0.24	†
	128	20	0.23	†
OO	129*	40	0.23	Broken (mostly WL)
	130*	40	0.23	†
	131	40	0.23	Broken (HAZ)
PP	133*	60	0.25	†
	135	60	0.28	Cracked completely (HAZ)
	136	60	0.27	†
QQ	137	80	0.33	†
	138	80	0.32	Cracked $1^1/_4$ in. (HAZ)
	139	80	0.35	†
RR	141	100	0.59	†
	142	100	0.55	Not stress relieved
	144	100	0.55	Cracked 1 in. (HAZ)

* Indicates specimens which exhibited flat-spots.
† Indicates specimens broken in previous testing.
‡ HAZ, Heat-affected zone.
§ WL, Weld line.

results of welds in 4340 steel, is evident in the generally high values of elongation and bend angle obtained. The decreased propensity for brittle failure permitted bending to be stopped, in most instances, when the initial crack had grown to the desired 1/16 in. length. Furthermore, of the total of 36 welds tested, 11 welds were completely crack-free, and 14 others exhibited cracks of only pinhole size.

Inspection of Tables 11 and 12 reveals almost all observed cracks occurred at the weld line in the 4130 grade. In this respect the welds in 4130 steel differ from those in the 4340 grade in which the location of failure depended upon the upset distance. Only one small heat-affected-zone crack was observed in the 36 specimens of 4130 steel examined, and no failures were observed in the unaffected base metal.

Although other specimens may have contained flat spots, the higher weld

Table 11—Results of Guided-Bend Testing to Initial Failure (4130 Steel)

Platen acceleration, 0.05 ips². 4130 steel, normalized and stress relieved. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	Weld No.	Upset current phase setting, %	Upset current, density, amp/in.²	Total upset distance, in.	Outer fiber elongation, % in. 0.37 in.	Bend angle, deg	Location and No. of cracks HAZ*	WL†	Edge	Crack length, in.‡
G	25	0	...	0.16	20	86	..	1	..	1/16
	26	0	...	0.17	22	120		None		...
	28	0	...	0.16	16	59	..	3	..	(1) 1/16
H	29	20	4,300	0.18	22	127	..	1	1	1/16 edge
	31	20	4,100	0.15	22	128		None		...
	32	20	4,100	0.17	22	126		None		...
I	33	40	10,100	0.17	22	130		None		...
	34	40	10,100	0.16	19	80	..	2	..	(1) 1/16
	36	40	10,100	0.16	19	132	..	2	..	...
J	37	60	17,500	0.18	14	48	..	1	..	1/16
	38	60	17,500	0.18	19	102	..	3	..	...
	39	60	17,300	0.17	19	106	..	2	..	...
K	41	80	28,700	0.26	11	41	..	..	1	3/8
	42	80	28,300	0.26	19	132		None		...
	44	80	28,500	0.24	19	129		None		...
L	45	100	44,400	0.44	14	48	..	1	..	1/16
	46	100	45,400	0.45	16	128	..	1	..	...
	48	100	45,300	0.47	14	82	..	1	..	...

* HAZ, Heat-affected zone.
† WL, Weld line.
‡ Any crack not specifically described in this column was of pinhole size.

Table 12—Results of Guided-Bend Testing to Initial Failure (4130 Steel)

Platen acceleration, 0.02 ips². 4130 steel, normalized and stress relieved. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Upset force, 25 kips. Burn-off 0.55 in.

Group	Weld No.	Upset current phase setting, %	Upset current density, amp/in.²	Total upset distance, in.	Outer fiber elongation, % in 0.37 in.	Bend angle, deg	Location and No. of cracks HAZ*	WL†	Edge	Crack length, in.‡
GG	98	0	...	0.24	11	30	..	1	..	1/16
	99	0	...	0.25	19	124		None		...
	100	0	...	0.24	19	125		None		..
HH	101	20	3,900	0.26	19	130	1	1	..	...
	102	20	3,900	0.24	19	110	..	2	..	...
	103	20	4,000	0.25	19	132		None		...
II	105	40	9,800	0.26	19	77	..	1	..	...
	107	40	10,000	0.23	19	130		None		...
	108	40	10,000	0.24	19	128		None		...
JJ	109	60	18,700	0.30	22	134	..	1	..	...
	111	60	18,300	0.27	22	134	..	1	..	...
	112§	60	18,100	0.27	11	33	..	4	..	(1) 1/16
KK	114	80	28,400	0.38	19	76	..	3	..	...
	115	80	28,300	0.37	19	132	..	1	..	...
	116§	80	27,300	0.35	3	4	..	1	..	1/4
LL	118	100	44,000	0.56	19	80	..	3	..	(1) 1/8
	119	100	45,100	0.57	16	134	..	1	..	...
	120	100	43,800	0.58	19	132	..	2	..	...

* HAZ, Heat-affected zone.
† WL, Weld line.
‡ Any crack not specifically described in this column was of pinhole size.
§ Indicates specimens later found to exhibit flat spots.

ductility with the 4130 grade made positive identification of flat spots possible in only two of the 36 welds tested. Despite the limited information available on flat-spot occurrence in welds in 4130 steel, an interesting comparison with welds in the 4340 material is apparent. With 4340 steel it may be recalled, no flat spots were observed to occur in welds which had been upset a distance greater than 0.25 in. Furthermore, because of the tendency for ready failure at the weld line in the 4340 steel, detection of flat spots was a simple matter. However, with the 4130 grade, Table 12 shows flat spots occurred in welds made with upsets of 0.27 and 0.35 in. In both instances the upset values are greater than the minimum requirement observed with the 4340 grade for elimination of flat spots. In fact, in weld No. 116 a sizable flat spot was found even with a total upset 0.10 in. greater than

Table 13—Results of Full Guided-Bend Tests

Platen acceleration, 0.05 ips². 4130 steel, normalized and stress relieved. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	Weld No.	Upset current phase setting, %	Total upset distance, in.	Location and No. of cracks HAZ*	WL†	Edge	Comments	Flat-spots
G	25	0	0.16	..	1	..	1/16 in.	..
	26	0	0.17	..	None	‡	.....	..
	28	0	0.16	..	1	1	1/16 in. (WL), 1/2 in. (Edge)	..
H	29	20	0.18	..	..	1	1/16 in.	..
	31	20	0.15	..	None	‡	.....	..
	32	20	0.17	..	None	‡	.....	..
I	33	40	0.17	..	None	‡	.....	..
	34	40	0.16	..	2	..	1/16 in. and 1/8 in.	..
	35	40	0.16	..	None	‡	.....	..
J	37	60	0.18	..	1	..	3/8 in.	..
	38	60	0.18	..	None	‡	.....	..
	39	60	0.17	..	None	‡	.....	..
K	41	80	0.26	..	..	1	3/4 in.	..
	42	80	0.26	..	None	‡	.....	..
	44	80	0.24	..	None	‡	.....	..
L	45	100	0.44	..	1	..	1/16 in.	..
	46	100	0.45	..	None	‡	.....	..
	48	100	0.47	..	None	‡	.....	..

* HAZ, Heat-affected zone.
† WL, Weld line.
‡ Pinhole cracks have not been included in this table.

Table 14—Results of Full Guided-Bend Tests (4130 Steel)

Platen acceleration, 0.02 ips². 4130 steel, normalized and stress relieved. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	Weld No.	Upset current phase setting, %	Total upset distance, in.	Location and No. of cracks HAZ*	WL†	Edge	Comments	Flat-spots
GG	98	0	0.24	..	1	..	1/16 in.	..
	99	0	0.25	..	None	‡	.....	..
	100	0	0.24	..	None	‡	.....	..
HH	101	20	0.26	..	None	‡	.....	..
	102	20	0.24	..	None	‡	.....	..
	103	20	0.25	..	None	‡	.....	..
II	105	40	0.26	..	1	..	1/16 in.	..
	107	40	0.23	..	None	‡	.....	..
	108	40	0.24	..	None	‡	.....	..
JJ	109	60	0.30	..	None	‡	.....	..
	111	60	0.27	..	None	‡	.....	..
	112	60	0.27	..	..	..	Broken WL (20% ductile)	Several small
KK	114	80	0.38	..	None	‡	.....	..
	115	80	0.37	..	None	‡	.....	..
	116	80	0.35	..	..	..	Broken WL (30% ductile)	1 large, several small
LL	118	100	0.56	..	..	1	1/2 in.	..
	119	100	0.57	..	None	‡	.....	..
	120	100	0.58	..	None	‡	.....	..

* HAZ, Heat-affected zone.
† WL, Weld line.
‡ Pinhole cracks have not been included in this table.

Table 15—Results of U-Bend Testing to 1.5-In. Head Space (4130 Steel)

Platen acceleration, 0.05 ips². 4130 steel, normalized and stress relieved. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	*Weld No.*	*Upset current phase setting, %*	*Total upset distance, in.*	*Comments*
G	25	0	0.16	Cracked WL* 1/8
	26	0	0.17	None†
	28	0	0.16	Cracked WL 3/32 in. and Edge 1/4 in.
H	29	20	0.18	Cracked HAZ‡ 1/8 in. and WL 3/8 in.
	31	20	0.15	Cracked edge 1/8 in.
	32	20	0.17	None†
I	33	40	0.17	None†
	34	40	0.16	Cracked WL 3/16 in.
	36	40	0.16	None†
J	37	60	0.18	Cracked WL 3/8 in. and Edge 1/8 in.
	38	60	0.18	None†
	39	60	0.17	Cracked WL 1/16 in.
K	41	80	0.26	Cracked edge 3/4 in.
	42	80	0.26	Cracked WL 1/16 in.
	44	80	0.24	Cracked WL 3/16 in.
L	45	100	0.44	Cracked edge 3/8 in.
	46	100	0.45	Cracked WL 1/16 in.
	48	100	0.47	None†

* WL, Weld line.
† Pinhole cracks have not been included in this table.
‡ HAZ, Heat-affected zone.

Table 16—Results of U-Bend Testing to 1.5-In. Head Space (4130 Steel)

Platen acceleration, 0.02 ips². 4130 steel, normalized and stress relieved. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	*Weld No.*	*Upset current phase setting, %*	*Total upset distance, in.*	*Comments*
GG	98	0	0.24	Cracked WL* 1/8 in.
	99	0	0.25	None†
	100	0	0.24	None†
HH	101	20	0.26	None†
	102	20	0.24	Cracked WL 1/4 in. and Edge 1/4 in.
	103	20	0.25	Cracked edge 1/4 in.
II	105	40	0.26	Cracked WL 1/16 in.
	107	40	0.23	None†
	108	40	0.24	None†
JJ	109	60	0.30	None†
	111	60	0.27	None†
	112‡	60	0.27	Broken previously
KK	114	80	0.38	Cracked WL 1/8 in.
	115	80	0.37	Cracked WL 1/8 in.
	116‡	80	0.35	Broken previously
LL	118	100	0.56	Cracked edge 3/8 in.
	119	100	0.57	None†
	120	100	0.58	Cracked WL 1/4 in. and edge 1/8 in.

* WL, Weld line.
† Pinhole cracks have not been included in this table.
‡ Indicates specimens which exhibited flat spots.

that required to eliminate flat spots in the 4340 material.

Plots of the data taken from Tables 11 and 12 for elongation at initial cracking as a function of the total upset distance are shown in Fig. 5 for welds in 4130 steel. This figure, which is of the same form as Fig. 3 presented previously for 4340 steel, shows the outer-fiber elongation in a 0.37-in. gage length for welds having total upset distances ranging from 0.15 to 0.57 in. The increased ductility of the welds in 4130 steel is readily apparent by comparison of Figs. 3 and 5, for the 4340 and 4130 steels, respectively. In only one instance was an elongation of less that 10% observed at the point of initial failure and in this case the specimen contained a flat spot. Furthermore, it may be seen that of the 36 welds tested only four welds had elongations lower than 14%. Of these four welds, two are known to have contained flat spots.

Although increasing the upset distance was found to eliminate flat spots in welds in 4340, no correlation between the incidence of flat spots and the total upset distance was found with the 4130 steel. Comparison of Fig. 5, for welds in 4130, and Fig. 3, for welds in 4340, will verify this observation. For example, although no flat spots were observed in 4340 where upset distances greater than 0.25 in. were employed, the two flat spots observed in 4130 were associated with welds having upset distances of 0.27 and 0.35 in.

Figure 6 summarizes the initial-failure bend angles as a function of the total upset distance. These data were

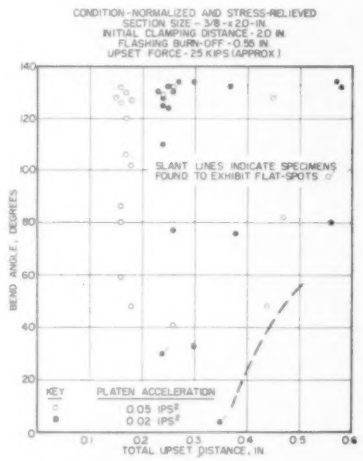

CONDITION - NORMALIZED AND STRESS-RELIEVED
SECTION SIZE - 3/8 x 2.0 IN.
INITIAL CLAMPING DISTANCE - 2.0 IN.
FLASHING BURN-OFF - 0.55 IN.
UPSET FORCE - 25 KIPS (APPROX.)
SLANT LINES INDICATE SPECIMENS FOUND TO EXHIBIT FLAT-SPOTS
BEND ANGLE, DEGREES
TOTAL UPSET DISTANCE, IN.
KEY
PLATEN ACCELERATION
0.05 IPS²
0.02 IPS²

Fig. 6 Bend angle at initial cracking as a function of total upset distance—AISI 4130 steel

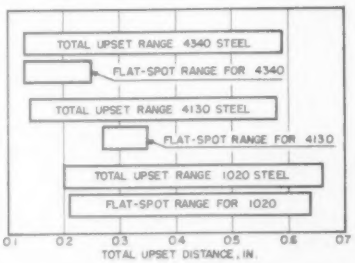

TOTAL UPSET RANGE 4340 STEEL
FLAT-SPOT RANGE FOR 4340
TOTAL UPSET RANGE 4130 STEEL
FLAT-SPOT RANGE FOR 4130
TOTAL UPSET RANGE 1020 STEEL
FLAT-SPOT RANGE FOR 1020
TOTAL UPSET DISTANCE, IN.

Fig. 7 Effect of upset distance on the occurrence of flat spots in welds in AISI 4340, 4130 and 1020 steel

taken from Tables 11 and 12 for welds in 4130 steel prepared at acceleration rates of 0.02 and 0.05 ips². Again it may be noted that those specimens which exhibited flat spots showed the lowest bend angle values. Most of the welds in this steel, however, exhibited considerable ductility prior to the occurrence of the initial failure. This is particularly apparent when the points of Fig. 6 are compared with those of Fig. 4 which summarizes the initial-failure bend angle as a function of total upset distance for welds in the 4340 material. Again, the increased ductility of welds in 4130 steel over those in 4340 steel when both are upset about 0.15 in. may be noted.

Table 17—Results of Guided-Bend Testing to Initial Failure (1020 Steel)

Platen acceleration, 0.05 ips². 1020 steel, as-welded. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	Weld No.	Upset current phase setting, %	Total upset distance, in.	Outer fiber elongation % in 0.37 in.	Bend angle, deg	Location and No. of cracks				Crack length, in.‡
						HAZ*	WL†	Edge	Base	
A	1	0	0.24	16	131	..	1	..	..	...
	3	0	0.24	16	130	..	None	..	..	...
	4	0	0.24	16	126	4	..	..	..	...
B	5	20	0.22	14	130	1	..	..	..	...
	7	20	0.21	14	131	3	..	..	..	...
	8	20	0.20	16	127	..	None	..	..	...
C	9	40	0.21	16	133	..	None	..	..	...
	11	40	0.23	14	82	1	1	..	..	1/8 WL
	12	40	0.23	14	130	..	None	..	..	...
D	13	60	0.26	16	135	..	None	..	..	...
	14	60	0.24	16	134	1	..	..	..	...
	15§	60	0.21	..	135	..	..	1	..	1/4
E	17	80	0.34	16	138	..	1	..	..	...
	18	80	0.37	16	130	1	1	..	..	1/16 WL
	20	80	0.38	16	110	2	1	..	..	...
F	21	100	0.61	18	138	1	..	..	..	...
	23	100	0.57	16	91	1	..	..	1	...
	24§	100	0.57	18	73	2	2	..	..	(1) 3/8 WL

* HAZ, Heat-affected zone.
† WL, Weld line.
‡ Any crack not specifically described in this column was of pinhole size.
§ Indicates specimens later found to exhibit flat spots.

Table 18—Results of Guided-Bend Testing to Initial Failure (1020 Steel)

Platen acceleration, 0.02 ips². 1020 steel, as-welded. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0. Burn-off, 0.55 in. Upset force, 25 kips

Group	Weld No.	Upset current phase setting, %	Total upset distance, in.	Outer fiber elongation % in 0.37 in.	Bend angle, deg	Location and No. of cracks			Crack length, in.‡
						HAZ*	WL†	Edge	
AA	73	0	0.31	16	76	8	..	..	...
	74	0	0.31	19	100	10	2	..	...
	75	0	0.30	16	71	§	§	..	...
BB	77	20	0.30	16	69	4	..	..	...
	78	20	0.30	16	70	3	..	..	...
	80	20	0.31	19	100	1	1	..	1/16 WL
CC	81	40	0.32	5	28	..	1	..	1/16
	82	40	0.31	22	127	6	..	1	3/8 edge
	83	40	0.32	16	81	8	..	..	...
DD	86	60	0.38	14	70	3	1	..	1/16 WL
	87	60	0.38	16	67	1	..	..	...
	88	60	0.35	22	128	5	..	..	...
EE	89	80	0.43	19	75	7	..	..	...
	90	80	0.41	16	62	10	..	..	...
	92‖	80	0.41	8	38	..	2	..	1/16 both
FF	93	100	0.64	11	44	5	..	..	...
	94‖	100	0.64	19	64	2	2	..	...
	95	100	0.64	22	86	§	§	...	...

* HAZ, Heat-affected zone.
† WL, Weld line.
‡ Any crack not specifically described in this column was of pinhole size.
§ Indicates the presence of numerous pinhole cracks along the weld line and throughout the heat-affected zone.
‖ Indicates specimens later found to exhibit flat spots.

Full Guided-Bend Tests of 4130 Steel

The results of the full guided-bend tests of welds in 4130 steel may be found in Table 13 for welds prepared at a platen acceleration of 0.05 ips², and in Table 14 for welds prepared at the 0.02 ips² rate. The large number of specimens which showed no cracks in this test reflects the ductile behavior encountered in welds in this material. Propagation of cracks observed in the initial-bend test was slow, and 24 of the total of 36 welds showed no cracks, other than pinholes, after full bending. Cracking, if it occurred, was observed only at the weld line, and the only complete fractures occurred in the two specimens (Nos. 112 and 116)

Table 19—Results of Full Guided-Bend Tests (1020 Steel)

Platen acceleration, 0.05 ips². 1020 steel, as-welded. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force 25 kips

Group	Weld No.	Upset current phase setting, %	Total upset distance, in.	Crack location and No. Base	HAZ*	WL†	Edge	Comments	Flat spots
A	1	0	0.24	..	None‡		..	...	...
	3	0	0.24	..	None‡		..	...	...
	4	0	0.24	..	None‡		..	...	...
B	5	20	0.22	..	None‡		..	...	...
	7	20	0.21	..	None‡		..	...	...
	8	20	0.20	..	None‡		..	...	...
C	9	40	0.21	..	None‡		..	...	...
	11	40	0.23	..	..	1	..	3/16	...
	12	40	0.23	..	None‡		..	...	...
D	13	60	0.26	..	None‡		..	...	...
	14	60	0.24	..	None‡		..	...	...
	15	60	0.21	..			1	3/8	1 small
E	17	80	0.34	..	None‡		..	...	...
	18	80	0.37	..	None‡		..	...	...
	20	80	0.38	..	None‡		..	...	...
F	21	100	0.61	..	None‡		..	...	...
	23	100	0.57	..	None‡		..	...	...
	24	100	0.57	..			..	Broken WL (10% ductile)	1 large

* HAZ, Heat-affected zone.
† WL, Weld line.
‡ Pinhole cracks have not been included in this table.

Table 20—Results of Full Guided-Bend Tests (1020 Steel)

Platen acceleration, 0.02 ips². 1020 steel, as-welded. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	Weld No.	Upset current phase setting, %	Total upset distance, in.	Crack location and No. Base	HAZ*	WL†	Edge	Comments	Flat spots
AA	73	0	0.31	..	None‡		..	...	...
	74	0	0.31	..	..	..	..	Many small HAZ cracks	...
	75	0	0.30	..	..	..	..	Many small HAZ cracks	...
BB	77	20	0.30	..	..	1	..	1/4 in.	...
	78	20	0.30	..	None‡		..	...	...
	80	20	0.31	..	None‡		..	...	...
CC	81	40	0.32	..	..	1	..	1/2 in.	...
	82	40	0.31	..	..	..	1	3/8 in.	...
	83	40	0.32	..	None‡		..	...	...
DD	86	60	0.38	..	..	..	1	1/8 in.	...
	87	60	0.38	..	None‡		..	...	...
	88	60	0.35	..	None‡		..	...	...
EE	89	80	0.43	..	None‡		..	...	...
	90	80	0.41	..	..	1	..	Cracked completely	...
	92	80	0.41	..	..	..	..	Broken WL (10% ductile)	1 large
FF	93	100	0.64	1	1	1	..	1/8 in. all	...
	94	100	0.64	..	..	..	..	Broken WL (20% ductile)	1 small
	95	100	0.64	..	None‡		..	...	...

* HAZ, Heat-affected zone
† WL, Weld line
‡ Pinhole cracks have not been included in this table.

which contained flat spots. The appearance of the fracture surface in these two specimens showed a notable lack of ductility. No definite correlation can be detected between weld quality and the amount of upset travel in these welds. The welds of Table 13, prepared at the more rapid, 0.05 ips² acceleration rate, appear to show a greater tendency for cracking than do the welds of Table 14, prepared at 0.02 ips². This may be due in part to the fact that the welds prepared at an acceleration rate of 0.05 ips² experienced less total upset than welds made at the slower flashing acceleration of 0.02 ips². However, the evidence is not conclusive because both specimens which broke during full bending were made at the slower, 0.02 ips² acceleration rate and were upset more than 0.25 in.

U-Bend Testing of Welds in 4130 Steel

Results of U bending and compression to 1.5-in. head space are presented in Tables 15 and 16 for welds prepared at acceleration rates of 0.05 and 0.02 ips², respectively. Little additional information may be gained by employing this test procedure on welds which are as ductile as those in 4130 steel in the normalized and stress-relieved condition. Complete fracture could not be induced in any additional welds. Comparison of the crack length data in Tables 15 and 16 indicates a slight increase in crack resistance in welds prepared at the slower rate of platen acceleration. However, the difference is not great and the observation has little practical significance.

Bend Test Results for 1020 Steel

Bending to Initial Failure

The bend test data for welds in 1020 steel, bent to initial failure, may be found in Tables 17 and 18. In Table 17 the elongation, angle of bend, severity of cracking and crack location are presented for welds prepared at an acceleration rate of 0.05 ips². Similar data are given in Table 18 for flash welds in 1020 steel prepared at the slower 0.02 ips² acceleration rate. Inspection of Table 17 reveals that with an acceleration rate of 0.05 ips² the range of upset distances could be varied from 0.20 to 0.57 in. by the application of upset current. Comparison with Table 18 reveals that, with the slower acceleration of 0.02 ips², the upset distances could be varied from 0.30 to 0.64 in. by the application of controlled amounts of upset current.

In general, the ductility of welds in the 1020 material is reflected in satisfactory values for both bend angle and elongation at initial failure. However, examination of data of Tables 17 and 18 shows that the ductility of welds in this material was best when upset travel of the order of 0.20 to 0.26 in. was employed, was definitely reduced by upset values above 0.40 in. and was erratic when the upset travel was intermediate to these ranges.

Again, as was found to be the case with 4130 steel, the ductility of the welds in the 1020 grade made impossible a thorough inspection for flat-spots. In the total sample of 36 welds in 1020 steel which were examined, only four welds were found which contained these defects. As may be seen in Tables 17 and 18 these flaws were found in specimens 15, 24, 92 and 94, for which the upset distances were 0.21, 0.57, 0.41 and 0.64 in., respectively. It should be noted that a major weld-line failure was detected in 3 of the 4 welds in the initial failure test.

Comparison of flat-spot data for all three steels employed in this investigation reveals that:

1. Flat-spots were avoided in the 4340 grade in welds upset more than 0.25 in.
2. The only flat-spots found in welds in 4130 steel were associated with specimens upset 0.27 and 0.37 in.
3. Flat-spots were detected in the 1020 material throughout practically the entire range of upset distances employed in specimen preparation.

Welds in the 1020 steel tended to show a number of early failures characterized by the appearance of a number of small cracks throughout the heat-affected zone. Although this cracking tendency was observed in welds which had moderate upset travel, it was more marked in those welds which were upset

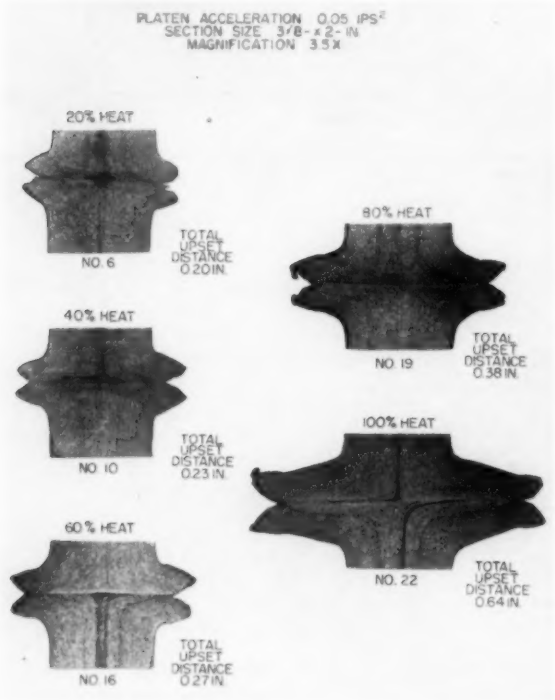


Fig. 8 Macrographs of flash welds in AISI 1020 steel—Platen acceleration, 0.05 ips². (Reduced by 1/2 upon reproduction)

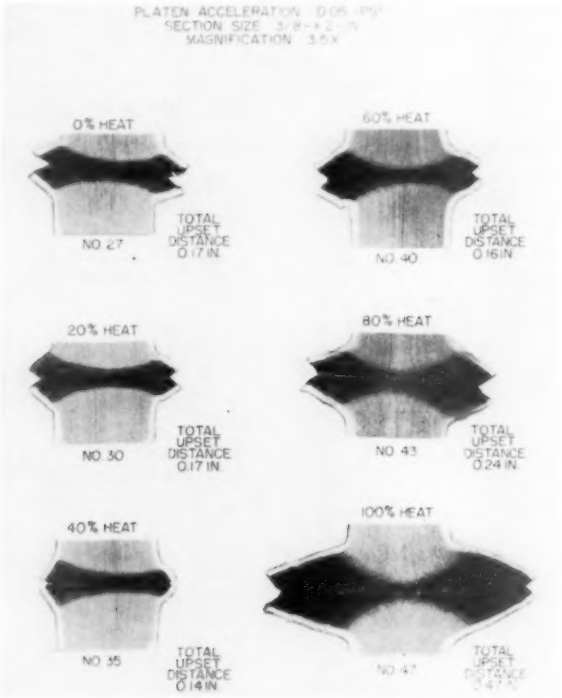


Fig. 9 Macrographs of flash welds in AISI 4130 steel—Platen acceleration, 0.05 ips². (Reduced by 1/2 upon reproduction)

to a greater degree. Many of these cracks, once they appeared, did not propagate across the surface of the specimen, but merely widened slightly with continued bending. This type of failure, at many sites throughout the heat-affected zone, is considered to be a consequence of the fact that the material near the weld line has a transverse fiber structure as a result of the upset action, and the bending stresses are therefore normal to the fiber structure. Therefore, inclusions and stringers act as stress raisers and cause premature cracking. Naturally, this tendency is more marked in those welds which have been upset to a greater distance where the rotation of the fiber structure is more pronounced. The effect of increased upset travel on the orientation of the fiber structure in the region of the weld will be discussed more completely in a later section of this report which deals with the metallographic studies of these welds.

Finally, it may be noted in Table 17 that the only failure which occurred in the unaffected base metal during initial testing was observed to have occurred in Specimen 23.

Full Guided-Bend Tests of 1020 Steel

Results of this testing procedure for specimens prepared at the more rapid, 0.05 ips², acceleration rate are shown in Table 19. In this table only the major cracks are tabulated, and the generally excellent quality of the welds prepared at this acceleration rate may be seen. Of the 18 welds, for which data are presented in Table 19, only three welds suffered major cracking or fracture, and two of these three welds were found to contain flat spots. However, comparison with the data in Table 20, for welds made with the 0.02 ips² acceleration rate reveals that the welds made at 0.02 ips² were not as satisfactory. Only seven welds in this series were found to be without major cracks after the full-bend test. The poorer over-all quality of the welds made with the 0.02 ips² acceleration rate is believed to reflect the fact that greater total upset distances and a greater tendency for a transverse fiber structure results from the slower flashing acceleration. Such a structure is unfavorably oriented to resist the stresses induced during bending, particularly where stringerlike inclusions are present, and, as a result, the material in the heat-affected zone tends to show numerous small, randomly distributed fissures. Fortunately, these cracks propagate slowly in material possessing the ductility of 1020 steel.

U-Bend Testing of Welds in 1020 Steel

Data obtained from welds in 1020 after U bending and compression may be found in Tables 21 and 22 for welds prepared at acceleration rates of 0.05 and 0.02 ips², respectively. It may be observed in these tables that cracking occurred predominantly in the heat-affected zone of welds in the 1020 grade material, and was generally of a ductile, shear-type nature. Only two welds (Nos. 5 and 12) both prepared at the more rapid acceleration rate, and having but 0.22 and 0.20 in. of upset travel, respectively, were found to have resisted major cracking. All the welds which were broken during any stage of testing had upset travel in excess of 0.41 in., and the remaining welds in the

Table 21—Results of U-Bend Testing to 1.5-In. Head Space (1020 Steel)

Platen acceleration, 0.05 ips². 1020 steel, as-welded. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	*Weld No.*	*Upset current phase setting, %*	*Total upset distance, in.*	*Comments*
A	1	0	0.24	Cracked HAZ* (100% ductile), 1 1/4 in.
	3	0	0.24	Cracked HAZ (100% ductile), 1 1/2 in.
	4	0	0.24	Cracked HAZ (100% ductile), 1 1/4 in.
B	5	20	0.22	None†
	7	20	0.21	Cracked HAZ (100% ductile), 1 in.
	8	20	0.20	None†
C	9	40	0.21	Cracked HAZ (100% ductile), 3/4 in.
	11	40	0.23	Cracked HAZ (100% ductile), 1 1/4 in.
	12	40	0.23	None†
D	13	60	0.26	Cracked HAZ (100% ductile), 1 3/4 in.
	14	60	0.24	Cracked HAZ (100% ductile), 1 in.
	15‡	60	0.21	Cracked HAZ (100% ductile), 1 3/4 in.
E	17	80	0.34	Cracked HAZ (100% ductile), 3/4 in.
	18	80	0.37	Cracked WL§ (100% ductile), 1/16 in.
	20	80	0.38	Cracked HAZ (100% ductile), 2 in.
F	21	100	0.61	Cracked WL (100% ductile), 1 3/4 in.
	23	100	0.57	Cracked WL (20% ductile), 2 in.
	24‡	100	0.57	Broken previously

* HAZ, Heat-affected zone.
† Pinhole cracks have not been included in this table.
‡ Indicates specimens which exhibited flat spots.
§ WL, Weld line.

Table 22—Results of U-Bend Testing to 1.5-In. Head Space

Platen acceleration, 0.02 ips². 1020 steel, as-welded. Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset force, 25 kips

Group	*Weld No.*	*Upset current phase setting, %*	*Total upset distance, in.*	*Comments**
AA	73	0	0.31	Cracked HAZ† (100% ductile), 1 3/4 in.
	74	0	0.31	Cracked HAZ (100% ductile), 1 7/8 in.
	75	0	0.30	Cracked HAZ (100% ductile), 1 7/8 in.
BB	77	20	0.30	Cracked HAZ (100% ductile), 1 1/2 in.
	78	20	0.30	Cracked HAZ (100% ductile), 1 1/2 in.
	80	20	0.31	Cracked HAZ (100% ductile), 1 3/4 in.
CC	81	40	0.32	Cracked mostly HAZ (100% ductile), 1 7/8 in.
	82	40	0.31	Cracked mostly HAZ (100% ductile), 2 in.
	83	40	0.32	Cracked HAZ (100% ductile), 1 1/4 in.
DD	86	60	0.38	Cracked mostly WL (20% ductile), 2 in.
	87	60	0.38	Cracked HAZ, 1/16 in.
	88	60	0.35	Cracked HAZ, 1/16 in.
EE	89	80	0.43	Cracked HAZ (100% ductile, 1 7/8 in.
	90	80	0.41	Broken WL‡ (75% ductile)
	92§	80	0.41	Broken previously
FF	93	100	0.64	Cracked HAZ (75% ductile), 2 in.
	94§	100	0.64	Broken previously
	95	100	0.64	Cracked mostly WL (20% ductile), 2 in.

* Pinhole cracks have not been included in this table.
† HAZ, Heat-affected zone.
‡ WL, Weld line.
§ Indicates specimens which exhibited flat spots.

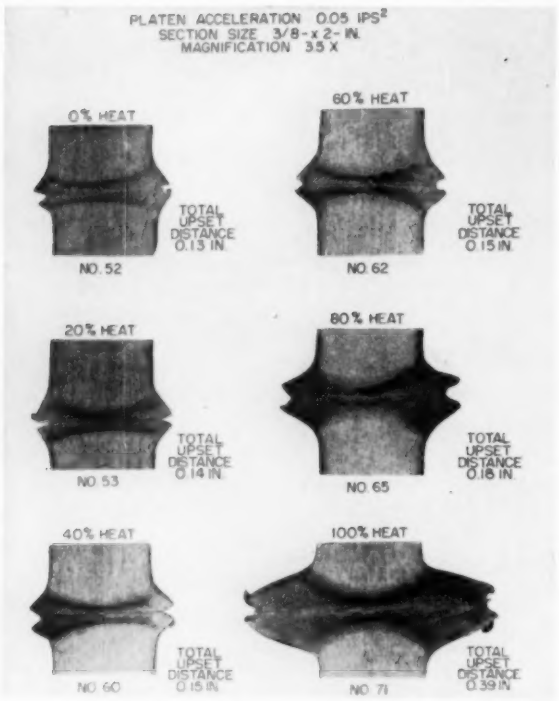


Fig. 10 Macrographs of flash welds in AISI 4340 steel—Platen acceleration, 0.05 ips². (Reduced by 1/2 upon reproduction)

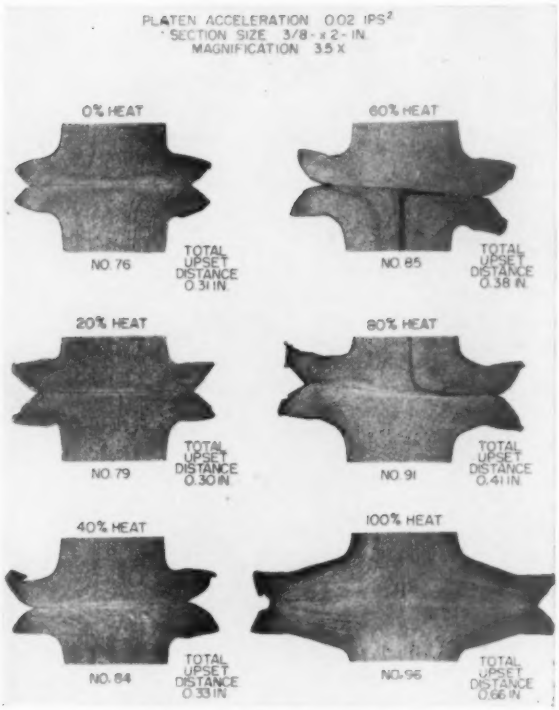


Fig. 11 Macrographs of flash welds in AISI 1020 steel—Platen acceleration, 0.02 ips². (Reduced by 1/2 upon reproduction)

0.41–0.64 in. upset distance range all showed severe cracking, generally extending across the entire specimen.

Summary of Bend Test Results

Effect of Upset Distance on Weld Quality

The ductility of welds in 4340 steel was found to increase continuously with increased upset travel beyond 0.15 in., and those welds prepared with maximum upset current generally showed the best crack resistance. No significant correlation could be observed between weld quality and total upset for welds in the more ductile 4130 steel. However, with the 1020 grade the ductility was best when the total upset distance was in the 0.20–0.26 in. range, was definitely reduced by upset greater than 0.40 in. and was erratic when the upset was intermediate to these ranges.

Location of Failure

In welds in 4340 steel the location of cracking or fracture was dependent upon the total upset distance employed in preparing the welds. When the total upset was less than 0.20 in., weld line failure predominated; when upset was greater than 0.20 in. there was an equal tendency for failure to occur at some other location in the heat-affected zone.

A similar correlation was not found for welds in 4130 steel. These welds failed, almost exclusively, at the weld line.

Failure in the 1020 grade was predominately in the heat-affected zone, and was characterized by the appearance of numerous small cracks assumed to be the result of the unfavorable orientation of the fiber structure. Such cracks tended to increase in number with increased total upset distance.

A comparison of the location of cracks in the three steels is apt to be misleading unless the differences in mechanical properties are also considered. The 4340 and 4130 steels, being of high hardenability, exhibit completely martensitic structures at the weld line when examined in the as-welded condition. On the other hand, the AISI 1020 steel has a microstructure composed principally of ferrite and finely laminated pearlite. Therefore, the 4340 and 4130 steels were normalized and then drawn at 1100° F prior to testing, while the 1020 steel was tested in the as-welded condition. The observed hardnesses in the testing condition ranged from VPN 255 for the 4340, and VPN 200 for the 4130, to VPN 180 for the 1020. Because of these differences in hardness, the rate of crack propagation would be expected to be greatest for the 4340 and least for the 1020, while the 4130 should exhibit an intermediate tendency to propagate a crack. Therefore, during bend testing of the harder 4340 steel, any minute defect might lead to the formation of a small crack which would tend to propagate rapidly until complete failure resulted with only small amounts of plastic deformation. With the softer 1020 steel, however, a defect of the same size would not necessarily lead to complete failure, since the rate of crack propagation is so low at room temperature that minute cracks would be arrested and the amount of plastic deformation required to produce failure would be very large. The behavior of the 4130 would be expected to be intermediate in view of the intermediate hardness level in the testing condition.

Therefore, the fact that the 4340 always failed at the weld line with upset distances of less than 0.2 in. may be explained, since the likelihood of the existence of minute flaws sufficient to cause cracking would be greatest at the weld line with low upset distances, and, once started, a single small crack would tend to propagate across the entire section as the plastic deformation progressed. With the 1020, however, the cracks originating from each minor defect are arrested and plastic deformation proceeds, allowing many tiny cracks to be formed. Where extreme amounts of upset are employed, the transverse nature of the fiber structure brings many stringer-type inclusions to the surface, each a potential origin of a crack during the bending test. Thus the numerous small cracks observed in the heat-affected zone of welds in AISI 1020 can be rationalized. On the other hand, as the upset is increased with the 4340, the chance of weld line defects is

reduced by the increased forging action, but the chances of stringer-type inclusions intersecting the surface in the heat-affected zone are increased. Therefore, it is not surprising that with increased upset some welds showed cracks in the heat-affected zone while others showed cracks only at the weld line.

The 4130 steel employed in this investigation was heavily decarburized and showed a severely banded structure. The fact that almost all failures in this material originated at the weld line is believed to be associated with the existence of banding, but definite proof of this belief has not yet been established. Further work is now in progress, however, to resolve this question.

Occurrence of Flat Spots

Flat spots were detected in 18 welds in 4340 steel, in two welds in 4130 steel and in four welds in 1020 steel. In all three grades the presence of flat spots generally resulted in reduced ductility and lessened resistance to cracking. As shown in Fig. 7 the range of total upset distance in which these defects were found to occur differed for the three steels. Figure 7 indicates the range of total upset distances produced in welds in 4340, 4130 and 1020 steel by control of upset current, and also shows the range of upset in which flat spots were observed. It may be seen that with 4340 steel flat-spot formation was avoided when the total upset was greater than 0.25 in. However, flat spots were noted in 4130 steel with upset travel as great as 0.35 in., and flat spots in welds in the 1020 grade occurred over the entire upset range.

Weld-Line Cracks

The weld-line surfaces of four welds in 4340 steel showed indications of cracking which occurred prior to or during heat treatment. Since these welds were prepared with less than 0.16-in. total upset distance, it may be that such cracks are a consequence of insufficient upset.

With the more ductile 1020 and 4130 steels the minimum total upset distances were 0.20 in. and 0.16 in., respectively, and in these grades, heat-treatment cracks were not observed.

Metallographic Studies of Flow-Line Orientation

One specimen was selected for metallographic examination from each of the 36 groups of four welds prepared at particular combinations of acceleration and upset current density. The conditions employed in preparing the specimens selected are summarized in Table 23 for welds prepared at an acceleration rate of 0.05 ips², and in Table 24 for welds flashed at the 0.02 ips² rate.

An aqueous 10% solution of ammonium persulfate was employed to reveal the flow lines. Satisfactory etching was obtained when the solution was employed at room remperature on the alloy specimens, and at the boiling point on specimens of plain-carbon steel. All welds were examined in the as-welded condition.

Influence of Upset Distance on Flow-Line Orientation

Macrographs of the flow-line patterns in welds flashed at 0.05 ips² are shown in Figs. 8, 9 and 10 for welds in 1020, 4130 and 4340 steels, respectively. Similar photomacrographs are shown in Figs. 11, 12 and 13 for welds flashed at the 0.02 ips² acceleration rate in 1020, 4130 and 4340 steels, repectively. In each of these figures it may be noted that there is no significant increase in upset distance or change in the orientation of the fiber structure near the weld line until more than 40% of full-phase current is employed, during upset. This 40% heat value, as shown in the data of Tables 23 and 24, corresponds to an upset current density of approximately 10,000 amp/in.² When

Table 23—Summary of Conditions Employed in Preparing Specimens for Metallographic Examination

Platen acceleration, 0.05 ips². Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Condition, as-welded

Group	*Weld No.*	*Steel*	*Upset current phase setting, %*	*Upset current density, amp/in.²*	*Upset force, kips*	*Total upset distance, in.*
A	2	1020	0	...	24.9	0.23
B	6	1020	20	4,300	24.2	0.20
C	10	1020	40	10,500	24.3	0.23
D	16	1020	60	18,500	23.6	0.27
E	19	1020	80	28,800	24.6	0.38
F	22	1020	100	45,900	23.9	0.64
G	27	4130	0	...	24.3	0.17
H	30	4130	20	4,300	25.2	0.17
I	35	4130	40	10,300	24.8	0.14
J	40	4130	60	17,900	24.4	0.16
K	43	4130	80	28,200	24.4	0.24
L	47	4130	100	45,400	24.2	0.47
M	52	4340	0	...	24.8	0.13
N	53	4340	20	4,200	25.6	0.14
O	60	4340	40	10,200	25.1	0.15
P	62	4340	60	18,000	25.4	0.15
Q	65	4340	80	27,500	24.9	0.18
R	71	4340	100	43,100	23.9	0.39

Table 24—Summary of Conditions Employed in Preparing Specimens for Metallographic Examination

Platen acceleration, 0.02 ips². Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Condition, as-welded

Group	*Weld No.*	*Steel*	*Upset current phase setting, %*	*Upset current density, amp/in.²*	*Upset force, kips*	*Total upset distance, in.*
AA	76	1020	0	...	25.4	0.31
BB	79	1020	20	4,200	24.0	0.30
CC	84	1020	40	10,800	23.7	0.33
DD	85	1020	60	19,200	23.9	0.38
EE	91	1020	80	29,200	23.6	0.41
FF	96	1020	100	45,100	24.1	0.66
GG	97	4130	0	...	25.1	0.26
HH	104	4130	20	4,200	25.1	0.25
II	106	4130	40	10,300	24.9	0.24
JJ	110	4130	60	18,100	25.3	0.28
KK	113	4130	80	27,900	24.9	0.34
LL	117	4130	100	45,400	24.5	0.57
MM	121	4340	0	...	26.1	0.23
NN	127	4340	20	3,900	26.5	0.24
OO	132	4340	40	9,900	26.5	0.25
PP	134	4340	60	17,800	26.4	0.27
QQ	140	4340	80	27,700	26.1	0.34
RR	143	4340	100	44,000	25.4	0.56

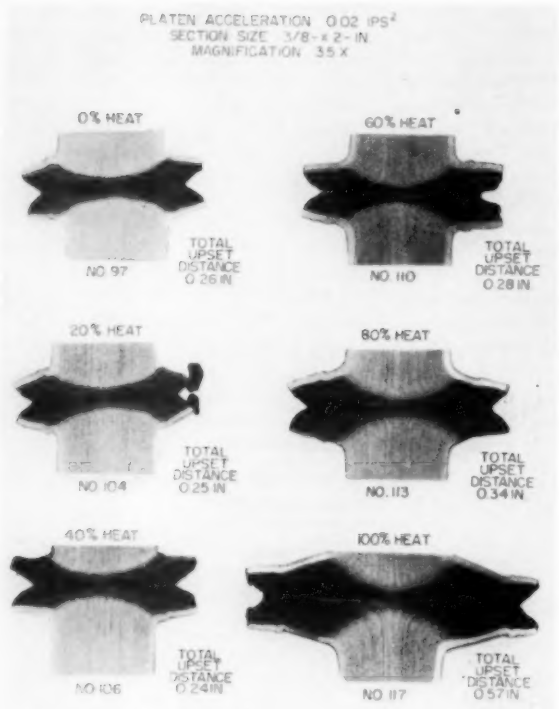


Fig. 12 Macrographs of flash welds in AISI 4130 steel—Platen acceleration, 0.02 ips². Reduced by 1/2 upon reproduction)

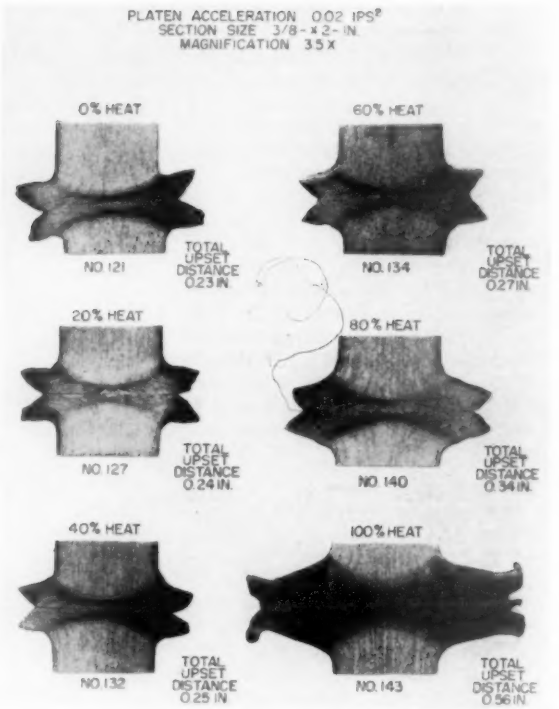


Fig. 13 Macrographs of flash welds in AISI 4340 steel—Platen acceleration, 0.02 ips². (Reduced by 1/2 upon reproduction)

upset current densities greater than 10,000 amp/in.² are used, however, inspection of the macrographs shows that there is a progressive increase in upset distance, and the fiber structure near the weld line is increasingly deformed. It is such fiber orientation which may account for the numerous, small, heat-affected-zone cracks observed during the bend testing of welds in 1020 steel. These cracks, it will be recalled, were more prevalent in welds prepared with large upset distances.

Actually, the results of the increase in upset travel are twofold; the fiber structure becomes more sharply bent in a direction normal to the axis of the weld, and there is an increased volume of metal in which disruption of the fiber structure is present. A typical example of the influence of upset distance on bending of the fiber structure may be seen in the macrographs of Fig. 9, in which the flow lines are particularly well defined. Inspection of the flow-line patterns in the welds prepared with 40, 60, 80 and 100% upset heat, for which the respective upset distances are 0.14, 0.16, 0.24 and 0.47 in., reveals progressive increase both in fiber bending and in the volume of the zone in which the deformation exists. After flash removal, welds such as No. 47, prepared with maximum upset current, show a relatively wide zone of material, centered about the weld line, in which the fiber structure is found to be nearly normal to the surface of the specimen.

There is no significant difference in the degree of fiber deformation which may be observed in welds prepared in steels of differing elevated-temperature strength, if the welds are flashed at the same acceleration rates and are upset the same amount. More upset current heating is, of course, required to produce equal plasticity in a weld in an alloyed steel, compared to a weld in plain-carbon steel. But, when the alloyed steel has been heated to temperatures where yielding occurs under the applied force, the modes of deformation, appear to be the same.

Influence of Platen Acceleration on Flow-Line Orientation

Deformation in the metal near the weld line may be shown to be dependent on the rate of acceleration employed during flashing. The influence of the rate of acceleration arises from the difference in the temperature distributions established in welds prepared at dissimilar rates of acceleration. The influence of the platen acceleration is not as pronounced as the effect of upset distance on the deformation during upset. The stable-temperature distributions established in the welds made for this study were presented in Table 2. As may be seen by inspection of this table, the use of the slower, 0.02 ips², acceleration results in higher temperatures in the material adjacent to the flashing interface than are obtained when the 0.05 ips² acceleration is employed. Therefore, in welds flashed at the slower rate, the higher-temperature metal presents less resistance to deformation during upset, and, more severe reorientation fiber structure results.

This trend toward increased severity of fiber bending with slower platen acceleration may be observed by comparison of the structures of Figs. 8, 9 and 10, for welds made at 0.05 ips², with the structures shown in Figs. 11, 12 and 13 for welds flashed at the slower rate. However, since the degree of deformation is dependent upon the upset distance obtained, the effect of acceleration is more properly determined by comparison of welds which have been upset identical amounts. Macrographs of such welds are presented in Fig. 14. In this figure it may be seen that the fiber reorientation in the two welds made with the slower acceleration rate is more pronounced than that which has occurred in the welds flashed at the more rapid 0.05 ips² rate, although the respective upset distances are identical.

Flat-Spot Studies

Metallography of Welds in 4340 Steel

Several welds in 4340 steel for which the total upset distance was 0.15 in. or less, showed light-etching regions at the weld line when etched with the 10% ammonium persulfate solution. One

such region, of large size, is visible in weld No. 53 shown in Fig. 10. The light area may be seen to be a narrow band extending more than one-third of the length of the weld line, and, in this macrograph, it appears that the lighter area is separated from the adjacent material by a dark-etching boundary. This "boundary" was found to be the result of the selective attack of the etching reagent, since subsequent examination, after the specimen was repolished and etched with Nital, did not show a well-defined demarcation between the light-etching and dark-etching material. A weld-line crack which terminated outside of the light-etching area was also noted in this specimen.

Photomicrographs of the light-etching band are shown at magnifications of 100× and 1000× in Fig. 15. The microstructure of the material within and adjacent to the band appeared to be martensitic. This structure would be anticipated considering the high hardenability of 4340 steel and the rates of cooling known to occur at the weld line of flash welds.[5] Microhardness measurements revealed a hardness in the range 708 to 795 VPN for the light-etching material in the as-welded condition. An attempt was made to fracture specimen No. 53 at the weld line in order that the weld faces could be examined. However, fracture could not be promoted at the weld line in this as-welded material, owing to the high hardness of the material in the heat-affected zone and the extremely small size of the specimen.

Fortunately, a supply of welds in 4340 steel, for which the welding conditions were known, were available in this laboratory, and metallographic examination revealed that several of these welds, when etched with 2% Nital, also showed light-etching regions at the weld line. The microstructures were similar to that of weld No. 53 shown in Fig. 15. However, the light etching areas were smaller and did not appear as light as that in the original specimen. Microhardness measurements showed the hardness values in the light-etching bands to range between 650 and 735 VPN with a hardness of 550 to 600 VPN occurring in the darker material immediately adjacent to the band. In order to eliminate the possibility that the high hardness of the light-etching region was caused by the presence of carbides or nitrides, one specimen was tempered for 30 min at 600° F. Subsequent examination showed a decrease in the width of the light-etching region, some darkening of the material in this zone, and a decrease in hardness to 520–600 VPN, indicating that the original material was a high-carbon martensite.

Several welds which exhibited these martensitic regions at the weld line were selected for bend testing. These specimens were normalized and stress relieved in order to promote weld-line failure and repolished and etched so that the limits of the white regions could be established. Light scribe lines were used on the surface to mark the location of the light-etching regions. After fracture, large flat spots were found to intersect the polished surfaces of these specimens between the scribed limits of the martensite bands.

Metallography of Welds in 1020 Steel

After etching in 10% ammonium persulfate, several large stringers were visible in the microstructures of welds in 1020 steel. Such stringers may be seen in weld No. 22 in Fig. 8, and also in welds Nos. 85 and 91 in Fig. 11. In these figures, the stringers appear as dark bands, deformed during upset so that they extend along the weld line for a considerable distance. Stringer formation in weld No. 22 was particularly marked; therefore, this weld was selected for further metallographic examination. The specimen was etched with Nital and examined at 100×.

The single, dark stringer visible in weld No. 22 was found to be composed of several parallel bands of pearlite, between which were regions of approximately equal width in which the structure was low-carbon ferrite. Because of the severe deformation of the microstructure which occurred during upset, it was not possible to determine either the presence, or absence, of martensite in the regions where the pearlitic bands extended to the weld line.

X-Ray Diffraction of Flat Spots

X-ray diffraction techniques were employed to determine whether the presence of any unsuspected constituents could be detected in a flat spot.

Two techniques were employed: (1) Examination of metal powder collected from the surface of a flat spot and (2) examination of the thin edge of a diagonally sliced flat spot.

Since no dissimilarity could be found in the diffraction patterns obtained with the above samples when they were compared with patterns obtained with welds which did not show flat spots, this line of investigation was discontinued.

Summary of Flat-Spot Studies

It is a widely accepted belief that flat spots are a consequence of contamination of the flashing interfaces by gas from the atmosphere. Contamination, it is proposed, may result from adsorbtion or solution of gas or by reactions between gas and hot metal forming an unspecified non-metallic film on the interfaces. A flat spot is believed to result if this film is incompletely extruded during upset. As a result high flashing voltages are avoided, since high voltage causes deeper expulsion cavities and increases the probability of entrapped contamination. Furthermore, a protective atmosphere is often employed in an attempt to avoid the formation of oxides or nitrides on the flashing surfaces.

In the present study, the fact that flat spots in 4340 steel were avoided by employing total upset distances greater than 0.25 in. is compatible with the gas-contamination hypothesis. It is conceivable that during flashing expulsion cavities of the order of $^1/_8$ in. in depth might occur in the interfaces of

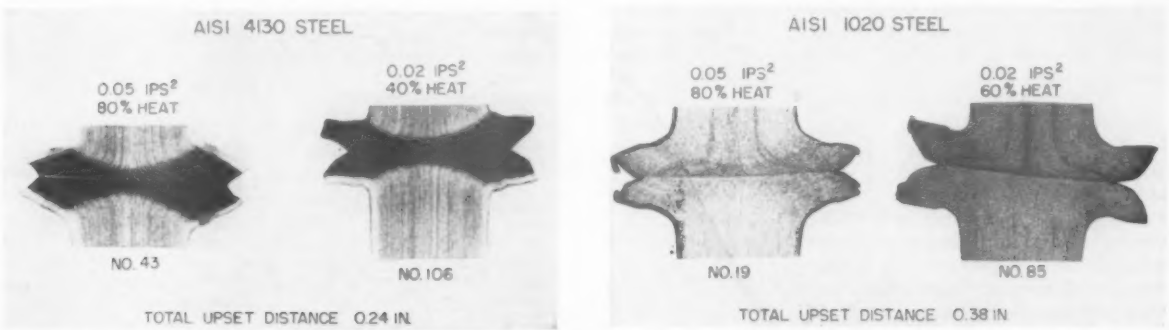
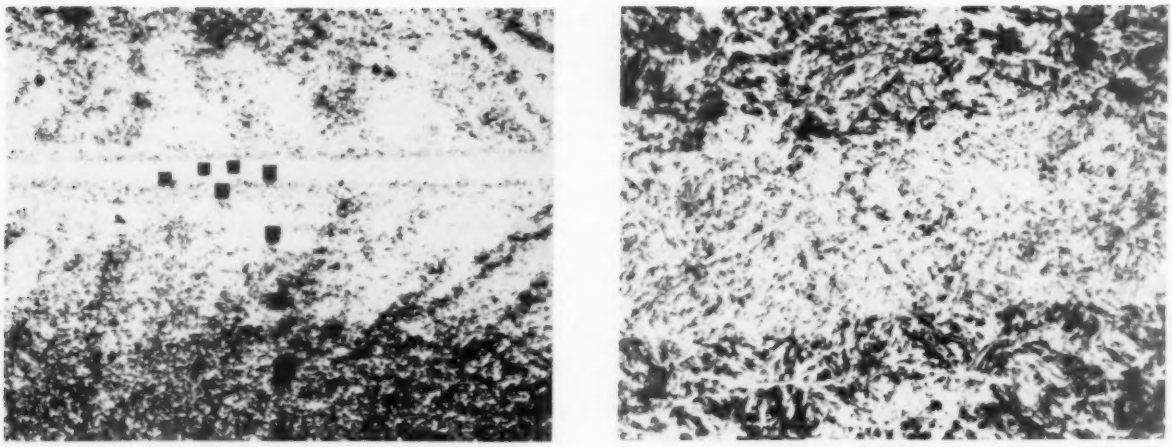


Fig. 14 Macrographs showing the influence of platen acceleration on the orientation of the fiber structure. Section size $^3/_8$ x 2 in. X 3.5. (Reduced by $^1/_2$ upon reproduction)



X 100 X 1000

Fig. 15 Photomicrographs of the high-carbon martensitic structure observed at the weld line of weld No. 53. (Reduced by 14% upon reproduction)

these welds, and, it is possible that after 0.25-in. total upset had occurred, all of the trapped non-metallic was extruded into the flash.

However, the gas-contamination mechanism is not satisfactory in explaining the occurrence of flat spots in welds subjected to extreme upset travel. For example, consider two of the welds in 1020 steel, Nos. 24 and 94. Both of these welds showed flat-spots after welding despite total upset values of 0.57 in. and 0.64 in., respectively. If the gas-contamination concept is valid in these cases, it leads to the conclusion that expulsion cavities about 0.28 to 0.32 in. deep existed in these interfaces prior to upset, or that the nonmetallic layer in the cavities was somehow translated through the plastic metal to assume a new position on the weld line. Both alternatives appear equally improbable. Further doubt of the validity of the gas-contamination mechanism is introduced by consideration of the following observations:

1. The complete elimination of flat spots is not accomplished even through the use of the lowest practical flashing voltage and protective gas atmospheres.
2. No comprehensive study of the effect of flashing voltage on the incidence of flat spots has been reported.
3. Welds in aluminum alloys rarely exhibit flat spots although the formation of an adherent refractory oxide is extremely rapid in these alloys.
4. X-ray diffraction studies and metallographic examinations do not reveal the presence of any unusual constituents in the vicinity of flat spots.

If the above objections to the gas-contamination hypothesis are valid, then some other mechanism must be assumed responsible for the occurrence of flat spots. The preliminary work performed by the authors suggests that carbon segregation may be responsible for the production of flat spots. Specifically, it is believed that the times involved in flash welding are too short to permit homogenization of the austenite formed in the weld region. Therefore, where pearlitic areas existed in the original material, the carbon content of the austenite might approach 0.8% regardless of the nominal carbon content of the steel. This, in turn, would provide local areas of high hardenability which when exposed to the rapid cooling rates near the weld line would transform to a high-carbon martensite. (This behavior has been observed in some instances in the vicinity of arc welds in low- and medium-alloy steels.)

Preliminary metallographic work has demonstrated that flat spots are found to exist on the fracture surfaces at the exact locations where a light etching microconstituent appears at the weld line. Micro-hardness measurements indicate that the hardness of such light-etching areas is greater than the hardness of the surrounding material, thus supporting the high-carbon martensite hypothesis.

Conclusions

1. The ductility of welds in AISI 4340 steel was found to increase continuously with increased upset travel beyond 0.15 in., and those welds prepared with maximum upset current exhibited the best crack resistance.
2. No significant correlation could be found between weld quality and total upset distance for welds in AISI 4130 steel.
3. For welds in 1020 steel the ductility was best when the total upset distance was between 0.20 and 0.26 in., was reduced by upset travel in excess of 0.40 in. and was erratic when the upset was intermediate to these ranges.
4. In welds in 4340 steel the location of failure during bend testing was dependent on the total upset distance employed in preparing the welds. When the total upset was less than 0.20

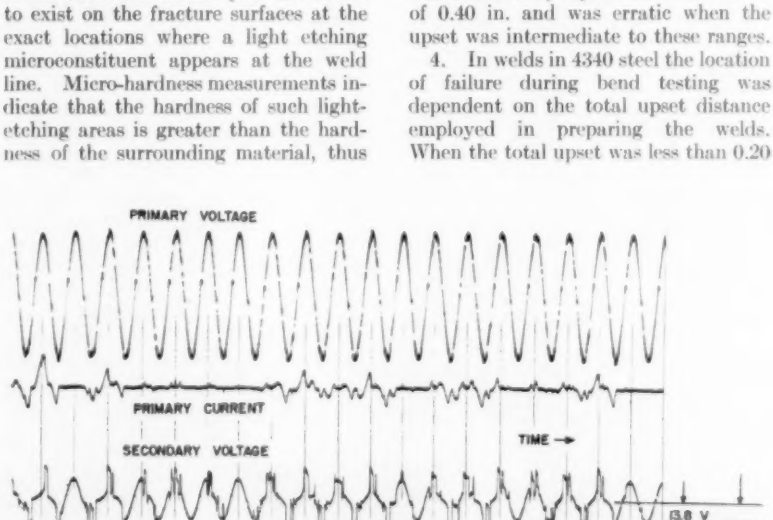


Fig. 16 Oscillograms showing the modification of flashing behavior caused by changing the reactance of the secondary loop

in., weld-line failure predominated; when upset was greater than 0.20 in. there was an equal tendency for failure to occur at some other location in the heat-affected zone.

5. Welds in 4130 steel were observed to fail, almost exclusively, at weld line.

6. Failure in welds in the 1020 grade was predominately in the heat-affected zone, and was characterized by the appearance of numerous small cracks assumed to result from the unfavorable orientation of the fiber structure. Such cracks tended to be more numerous as the total upset distance was increased.

7. Flat spots were observed in all three steels employed in this investigation, but were much more numerous in welds in the 4340 grade. In all cases, the presence of flat spots resulted in decreased ductility and reduced resistance to cracking.

8. The range of total upset distance over which flat spots were observed to occur differed for the three steels employed. With the 4340 grade, flat-spot formation was avoided when the total upset was greater than 0.25 in. However, flat spots were detected in welds in 4130 steel upset as much as 0.35 in., and in welds in 1020 steel, flat spots occurred over the entire range of upset distances.

9. Weld-line cracks which occurred prior to or during heat treatment were observed in four welds in 4340 steel prepared with less than 0.16 in. total upset. It appears that these cracks may be a consequence of insufficient upset.

10. With a constant upsetting force, the degree of fiber-structure reorientation in the vicinity of the weld line was found to depend upon the upset distance and the platen acceleration employed during flashing. Increased upset and slower rates of acceleration result in the formation of a structure more nearly parallel to the weld line, and also result in an increased volume of material in which such orientation occurs.

11. There is no significant difference in the degree of fiber reorientation in welds in steels of differing elevated temperature strength, if the welds are flashed at the same rate and are upset the same amount.

Acknowledgment

The authors wish to acknowledge the financial support provided this investigation by the Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, under Contract No. AF18(600)-71. This project was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center. Lt. John F. Rudy and Lt. Robert M. Walkosak acted as Project Engineers under the direction of Robert Bowman, Chief of the Steel and Welding Section.

They also wish to acknowledge the advice and suggestions received from the Flash Welding Subcommittee of the Welding Research Council.

References

1. Nippes, E. F., Savage, W. F., McCarthy, J. J., and Patriarca, P., "Optimum Flash Welding Conditions for Aluminum Alloys," THE WELDING JOURNAL, **30** (12), Research Suppl., 585-s to 601-s (1951).
2. Moyer, E. E., and Savage, W. F., "A New Method of Controlling Platen-Displacement vs. Time During Flash Welding," AIEE Conference Report for AIEE Welding Conference held in Detroit, Mich., April 1952.
3. Nippes, E. F., Savage, W. F., McCarthy, J. J., and Smith, S. S., "The Temperature Distribution During the Flash Welding of Steel," THE WELDING JOURNAL, **30** (12), Research Suppl., 585-s to 601-s (1951).
4. Nippes, E. F., Savage, W. F., Smith, S. S., McCarthy, J. J., and Grotke, G., "Temperature Distribution During Flash Welding of Steel—Part II," *Ibid.*, **32** (3), Research Suppl., 113-s to 122-s (1953).
5. Nippes, E. F., Savage, W. F., Grotke, G., and Robelotto, S. M., "Study of the Cooling Rates in Flash Welds in Steel," *Ibid.*, **33** (7), Research Suppl., 339-s to 362-s (1954).
6. Spraragen, W., and Lengyel, B. A., "Physics of the Arc and the Transfer of Metal in Arc Welding," *Ibid.*, **22** (1), Research Suppl., 2-s to 42-s (1943).

APPENDIX I: A PRELIMINARY INVESTIGATION OF THE NATURE OF FLASHING

Introduction

The flashing portion of the flash welding operation serves a dual function:

1. To establish a satisfactory temperature distribution for the subsequent forging action accomplished by upset.
2. To create, on the flashing interfaces, a protective layer of molten metal which may be readily expelled during the initial instant of upset, taking with it all oxides and dissolved atmospheric gases, leaving the underlying solid interfaces metallurgically uncontaminated.

Considerable disagreement exists among investigators as to the nature of flashing however, some holding that the flashing action consists entirely of a series of intermittent short circuits, while others hold that the flashing action is predominantly arclike in character.

From a purely analytical standpoint neither of these mechanisms appears by itself to provide a satisfactory explanation of the nature of flashing. For example, the open-circuit secondary voltages normally employed in flash welding range from 3 to 10 v RMS. Since this corresponds to a range of peak voltages of from 4.25 to 14.14 v, and since Spraragen[6] indicates that for an arc between iron electrodes the sum of the anode and cathode drops is of the order of 25 v in air, it seems unlikely that the secondary circuit is capable of sustaining an arcing action during flashing.

On the other hand, the secondary circuit of a flash welder contains appreciable inductance, and the laws of electricity therefore forbid instantaneous changes in the magnitude of the secondary current since di/dt, the rate of change of current, must be finite in any inductive load. Thus, the flow of secondary current through a momentary short circuit between the flashing interfaces cannot be terminated instantaneously by expulsion of the metal at the short circuit. Rather, the secondary current must decrease to zero at a finite rate by some means whenever all short circuit paths are momentarily broken.

In order to study the mechanism of flashing it was therefore decided to conduct a preliminary investigation using high-speed motion pictures together with oscillographic measurements. The following section of this Appendix summarizes the preliminary investigation.

Experimental Procedure

Flash welds were made in the 300-kva flash welder at RPI and motion pictures were taken of portions of the flashing operation at 3000 frames/-second. The primary current, primary voltage and secondary voltage were recorded simultaneously using a recording oscillograph, and marker signals were employed to synchronize the recorded data with the motion pictures. Motion pictures and records were obtained at the same flashing velocity using two different open-circuit secondary voltages and two different transformer turns-ratios. Considerable difficulty was experienced in synchronizing the high-speed motion picture camera to allow photographing the desired portion of the flashing cycle, and therefore most of the data were obtained for constant flashing velocities.

In addition, a few cathode-ray oscillograms were taken of primary current and secondary voltage during the flashing using a 75-kva flash welder in the RPI laboratories.

Discussion of Results

On a microscopic scale, the flashing interfaces are relatively irregular and consist of myriads of tiny "hills" and "valleys." As the platen of the flash welder advances, the weld specimens approach one another until contact is made between the two interfaces by

the meeting of two or more opposing high spots on the interfaces. High-speed motion pictures confirm this mechanism and reveal that the area of contact so produced is normally only an extremely small fraction of the total cross-sectional area of the flashing interfaces. As soon as such contact is made, a low-resistance path is provided, and a secondary current builds up rapidly through the tiny short circuit, heating the material in the vicinity of the contact to incandescence. The high-speed motion pictures reveal that as the material forming the short-circuit path becomes molten, it is violently expelled, thus breaking the low-resistance path, and leaving small depressions in the flashing interfaces. This process of making and breaking short circuits normally is repeated many times in each half-cycle of line frequency, and the location of successive short circuits migrates over the interfaces in a random manner.

It could be clearly seen from the high-speed motion pictures that no continuous arcing action accompanies the flashing operation. In fact, at 3000 frames per second, sometimes 30 consecutive frames (half cycle of the 60 cps supply) would show no evidence of current flow. At other times, several short circuits were evident simultaneously at widely separated points on the flashing interfaces. Usually, each individual short circuit was terminated by almost explosive expulsion of the material from the short circuit area as small globules of molten metal.

As flashing progressed, the average temperature of the flashing interface was gradually increased to a point where the entire interface area was incandescent. During the initial portion of flashing, however, noticeable fluctuations in the apparent temperature were observed. That is, immediately after termination of an individual short circuit, a small area nearby glowed brilliantly, only to cool rapidly as heat flowed into the adjacent cooler metal. As the flashing proceeded, however, and the average interfacial temperature approached the melting point, the localized fluctuations became less apparent.

Oscillograms taken of primary voltage, secondary voltage and primary current during flashing established several interesting facts regarding the flashing operation.

1. As was suspected from viewing the high-speed motion pictures, the flashing current is definitely intermittent. This may be seen by examination of the primary current traces in Fig. 16, and noting that no measurable primary current flowed for a short interval folowing each burst of current. The individual bursts of primary current are believed to be associated with individual short circuits, and the duration of the current burst is believed to be related to the area of contact between the two interfaces. That is, if the contact area is small, then the energy required to heat the small volume of material involved to melting is also small, and time of current flow required to destroy the short circuit is small.

2. Comparison of the primary current oscillograms taken with a high secondary reactance with one taken with lower secondary reactance indicates that:

(*a*) As would be expected, the rate of increase of current (di/dt) is less with the higher secondary reactance than with the lower secondary reactance.

(*b*) The number of short circuits per second is less with the higher reactance secondary, there being about 4 short circuits per cycle with the higher reactance vs. about 5 per cycle with the lower reactance. It should be emphasized that the flashing velocities and flashing voltages were identical, and that the oscillograms were taken after the same amount of burn-off had occurred.

Since the burn-off rate is the same in both cases, it may be deduced that the pits produced in the flashing interface must be deeper with the high secondary reactance in order to remove the same volume of material per second with fewer short circuits. Since the inductance of the secondary was changed more than the resistance for the purpose of these measurements, the maximum short-circuit current is nearly the same in both cases. However, with the slower rate of current increase associated with the higher reactance, the area of the short circuits apparently increased due to the advance of the platen prior to the time the current was able to destroy the short-circuit path.

3. It is also of interest to note the variations in secondary voltage during flashing. The oscillogram of secondary voltage shown in Fig. 16 was taken with the higher secondary reactance, but the same trends were observed with lower secondary reactance. The open-circuit secondary voltage of 9.75 v RMS (13.8 v peak) may be seen essentially undisturbed at the extreme right during an interval when no secondary current flow occurred. During current flow, however, due to the resistive drop in the secondary, the voltage at the jaws may be seen to be only a fraction of the open-circuit voltage. (This is an inherent characteristic of the secondary of any welder, but the magnitude of the drop is believed to be excessive with the present RPI flash welder due to a poorly designed secondary loop.) It is of particular interest to note the variation in secondary voltage which occurs at the end of each individual current pulse, however. Note that at the exact instant that the primary current trace (second from the top, Fig. 16) reaches a maximum, the secondary voltage (third trace from the top) rises sharply to a maximum of the order of 20–25 v. The following explanation is advanced for this phenomenon:

(*a*) Whenever a short circuit is created between the flashing interfaces by the platen advance, the secondary current increases at a rate determined by the impedance of the system, and the primary current therefore increases accordingly.

(*b*) When the flow of secondary current has raised the temperature of the material at the short circuit to its melting temperature, the short circuit is broken by the violent expulsion of the molten material, and the impedance of the secondary increases instantaneously to a large value.

(*c*) However, the primary current, being, under normal conditions, at a maximum at this instant, cannot decrease instantaneously due to the inductance of the windings. Examination of the primary current trace reveals, however, that the rate of change of current (slope of the current trace) is much greater during the decay (at the right of the maxima) than during the rise (at the left of the maxima). Since the secondary voltage is proportional to the rate of change of the flux in the core, which in turn is proportional to the rate of change of primary current, the secondary voltage must rise sharply during the intervals of primary current decay. Since the current in the secondary is also at a maximum at the time of expulsion and since the secondary current cannot decay instantaneously due to the inductance of the secondary, it seems likely that some arcing must occur for a limited time following the destruction of a short-circuit path, providing no other path is available to the secondary current at that instant. This momentary arcing is believed possible in view of the magnitude of the secondary voltage induced by the associated change in primary current, but it is believed that the duration of arcing in the secondary is very short compared to the decay time for the primary current. The existence of such arcing would tend to limit the maximum secondary voltage measured at the jaws to the order of voltage required to maintain a metallic arc in air, which would explain why induced secondary voltage peaks seem to exhibit maxima in the range 20–24 v.

Thus, although the high-speed motion pictures do not indicate arcing during flashing, it is possible that a small amount of arcing occurs after removal

of individual short circuits. Such arcing would occur, however, only if the short circuit path removed were the only such path available at the time. If two or more short circuit paths were operating simultaneously, and one were removed, it would be expected that the current would increase in the remaining short circuit paths by an amount equal to the current interrupted by removing one short circuit. In any event, the disturbance in the secondary circuit resulting from expulsion of material from an active short circuit is too short in duration to be observed with high-speed motion pictures, and the exact nature of the disturbance cannot be deduced from data presently available.

(*d*) The upper trace in Fig. 16 shows the primary voltage during flashing and it may be noted that the variation in primary voltage is negligibly small during flashing.

Conclusions

1. High-speed motion pictures and oscillographic records of primary voltage, primary current and secondary voltage indicate that flashing action consists predominantly of a series of intermittent short circuits.

2. Each individual short circuit is terminated by violent expulsion of the material forming the short circuit when this material is heated above its melting temperature.

3. No evidence of arcing action can be seen in high-speed motion pictures of flashing.

4. If any arcing occurs, it can only occur for an extremely short interval following the expulsion of material from a short-circuit path, and is therefore not considered to contribute significantly to the over-all flashing operation.

APPENDIX II: WELDING CONDITIONS EMPLOYED FOR SPECIMEN PREPARATION

Platen acceleration, 0.05 ips^2. Section size, $^3/_8$ x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset current duration, 37 cycles (if employed)

Group	*Weld No.*	*Upset current phase setting, %*	*Upset current duration, sec*	*Upset current density, amp/in.^{2}*	*Upset force, kips*	*Total upset distance, in.*
			AISI 1020 steel			
A	1	0	...	...	24.7	0.24
	2*	0	...	...	24.9	0.23
	3	0	...	...	24.9	0.24
	4	0	...	...	25.0	0.24
					24.9 avg	0.24 avg
B	5	20	0.61	4,200	23.9	0.22
	6*	20	0.61	4,300	24.2	0.20
	7	20	0.62	4,300	24.4	0.21
	8	20	0.62	4,300	24.2	0.20
			0.62 avg	4,300 avg	24.2 avg	0.21 avg
C	9	40	0.63	10,600	23.7	0.21
	10*	40	0.62	10,500	24.3	0.23
	11	40	0.61	10,800	23.9	0.23
	12	40	0.63	10,600	23.6	0.23
			0.62 avg	10,600 avg	23.9 avg	0.23 avg
	13	60	0.62	18,600	23.7	0.26
	14	60	0.63	18,900	24.3	0.24
	15	60	0.62	18,500	23.9	0.21
	16*	60	0.63	18,500	23.6	0.27
			0.63 avg	18,600 avg	23.9 avg	0.25 avg
	17	80	0.61	28,500	24.6	0.34
	18	80	0.61	29,100	24.5	0.37
	19*	80	0.61	28,800	24.6	0.38
	20	80	0.60	28,900	24.2	0.38
			0.61 avg	28,800 avg	24.5 avg	0.37 avg
	21	100	0.62	46,200	23.5	0.61
	22*	100	0.63	45,900	23.9	0.64
	23	100	0.62	46,800	24.2	0.57
	24	100	0.63	44,600	23.9	0.57
			0.63 avg	45,900 avg	23.9 avg	0.60 avg

(*continued on page 214-s*)

Group	Weld No.	Upset current phase setting, %	Upset current duration, sec	Upset current density, amp/in.²	Upset force, kips	Total upset distance, in.
			AISI 4130 steel			
G	25	0	...	...	24.4	0.16
	26	0	...	...	24.8	0.17
	27*	0	...	...	24.3	0.17
	28	0	...	...	24.4	0.16
					24.5 avg	0.16 avg
H	29	20	0.62	4,300	26.0	0.18
	30*	20	0.61	4,300	25.2	0.17
	31	20	0.62	4,100	24.9	0.15
	32	20	0.61	4,100	25.0	0.17
			0.62 avg	4,200 avg	25.3 avg	0.17 avg
I	33	40	0.61	10,100	24.9	0.17
	34	40	0.63	10,100	24.9	0.16
	35*	40	0.61	10,300	24.8	0.14
	36	40	0.62	10,000	24.7	0.16
			0.62 avg	10,100 avg	24.8 avg	0.16 avg
J	37	60	0.61	17,500	25.1	0.18
	38	60	0.62	17,500	24.7	0.18
	39	60	0.61	17,300	24.8	0.17
	40*	60	0.61	17,900	24.4	0.16
			0.61 avg	17,600 avg	24.5 avg	0.18 avg
K	41	80	0.62	28,700	24.6	0.26
	42	80	0.63	28,300	24.8	0.26
	43*	80	0.61	28,200	24.4	0.24
	44	80	0.63	28,500	24.3	0.24
			0.62 avg	28,400 avg	24.5 avg	0.25 avg
L	45	100	0.63	44,400	24.4	0.44
	46	100	0.63	45,400	24.2	0.45
	47*	100	0.63	45,400	24.2	0.47
	48	100	0.63	45,300	24.3	0.47
			0.63 avg	45,100 avg	24.3 avg	0.46 avg
			AISI 4340 steel			
M	49	0	...	...	25.4	0.14
	50	0	...	...	25.1	0.15
	51	0	...	...	25.0	0.14
	52*	0	...	...	24.8	0.13
					25.1 avg	0.14 avg
N	53*	20	0.61	4,200	25.6	0.14
	54	20	0.61	4,000	25.6	0.14
	55	20	0.61	4,200	25.4	0.13
	56	20	0.61	4,000	25.5	0.13
			0.61 avg	4,100 avg	25.5 avg	0.14 avg
O	57	40	0.60	10,300	25.7	0.13
	58	40	0.61	10,300	25.7	0.14
	59	40	0.61	10,200	25.3	0.14
	60*	40	0.61	10,200	25.1	0.15
			0.61 avg	10,300 avg	25.5 avg	0.14 avg
P	61	60	0.61	18,300	25.0	0.18
	62*	60	0.61	18,000	25.4	0.15
	63	60	0.61	17,900	25.5	0.15
	64	60	0.62	18,000	25.1	0.15
			0.61 avg	18,100 avg	25.3 avg	0.16 avg
Q	65*	80	0.63	27,500	24.9	0.18
	66	80	0.62	27,700	24.7	0.18
	67	80	0.62	28,000	24.3	0.21
	68	80	0.62	28,000	24.7	0.19
			0.62 avg	27,800 avg	24.7 avg	0.19 avg

(continued on page 215-s)

Group	Weld No.	Upset current phase setting, %	Upset current duration, sec	Upset current density, amp/in.²	Upset force, kips	Total upset distance, in.
R	69	100	0.62	43,600	24.0	0.38
	70	100	0.60	44,000	24.3	0.37
	71*	100	0.61	43,100	23.9	0.39
	72	100	0.61	44,200	24.8	0.41
			0.61 avg	43,700 avg	24.3 avg	0.39 avg

•

Platen acceleration, 0.02 ips². Section size, 3/8 x 2.0 in. Initial clamping distance, 2.0 in. Burn-off, 0.55 in. Upset current duration, 37 cycles (if employed)

AISI 1020 steel

AA	73	0	...	...	25.8	0.31
	74	0	...	...	25.7	0.31
	75	0	...	...	25.8	0.30
	76*	0	...	...	25.4	0.31
					25.4 avg	0.31 avg
BB	77	20	0.62	4,300	25.2	0.30
	78	20	0.60	4,000	24.0	0.30
	79*	20	0.60	4,200	24.0	0.30
	80	20	0.60	4,200	24.5	0.31
			0.61 avg	4,200 avg	24.4 avg	0.30 avg
CC	81	40	0.61	10,500	24.3	0.32
	82	40	0.60	10,600	24.0	0.31
	83	40	0.61	10,500	23.9	0.32
	84*	40	0.61	10,800	23.7	0.33
			0.61 avg	10,600 avg	24.0 avg	0.32 avg
DD	85*	60	0.61	19,200	23.9	0.38
	86	60	0.61	19,000	23.9	0.38
	87	60	0.60	18,600	24.2	0.38
	88	60	0.61	18,300	23.6	0.35
			0.61 avg	18,800 avg	23.9 avg	0.37 avg
EE	89	80	0.61	28,800	24.2	0.43
	90	80	0.61	29,000	23.5	0.41
	91*	80	0.62	29,200	23.6	0.41
	92	80	0.61	29,000	23.8	0.41
			0.61 avg	29,000 avg	23.8 avg	0.42 avg
FF	93	100	0.60	45,700	24.0	0.64
	94	100	0.61	45,100	24.3	0.64
	95	100	0.61	46,200	24.0	0.64
	96*	100	0.61	45,100	24.1	0.66
			0.61 avg	45,500 avg	24.1 avg	0.65 avg

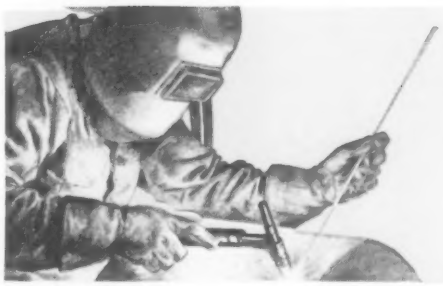
AISI 4130 steel

GG	97*	0	...	...	25.1	0.26
	98	0	...	...	25.2	0.24
	99	0	...	...	25.3	0.25
	100	0	...	...	24.9	0.24
					25.1 avg	0.25 avg
HH	101	20	0.60	3,900	24.8	0.26
	102	20	0.60	3,900	24.5	0.24
	103	20	0.61	4,000	25.0	0.25
	104*	20	0.60	4,200	25.1	0.25
			0.60 avg	4,000 avg	24.9 avg	0.25 avg
II	105	40	0.60	9,800	25.0	0.26
	106*	40	0.60	10,300	24.9	0.24
	107	40	0.60	10,000	25.1	0.23
	108	40	0.61	10,000	25.4	0.24
			0.60 avg	10,000 avg	25.1 avg	0.24 avg

(concluded on page 216-s)

Group	Weld No.	Upset current phase setting, %	Upset current duration, sec	Upset current density, amp/in.^{2}	Upset force, kips	Total upset distance, in.
JJ	109	60	0.60	18,700	24.9	0.30
	110*	60	0.60	18,100	25.3	0.28
	111	60	0.61	18,300	25.1	0.27
	112	60	0.61	18,100	24.5	0.27
			0.61 avg	18,300 avg	25.0 avg	0.28 avg
KK	113*	80	0.62	27,900	24.9	0.34
	114	80	0.62	28,400	25.0	0.38
	115	80	0.62	28,300	25.1	0.37
	116	80	0.61	27,300	24.3	0.35
			0.62 avg	28,000 avg	24.8 avg	0.36 avg
LL	117*	100	0.61	45,400	24.5	0.57
	118	100	0.62	44,000	24.7	0.56
	119	100	0.62	45,100	24.4	0.57
	120	100	0.62	43,800	24.7	0.58
			0.62 avg	44,600 avg	24.6 avg	0.57 avg
			AISI 4340 steel			
MM	121*	0	...	...	26.1	0.23
	122	0	...	...	26.5	0.24
	123	0	...	...	26.5	0.22
	124	0	...	...	26.4	0.24
					26.4 avg	0.23 avg
NN	125	20	0.61	3,900	26.4	0.24
	126	20	0.60	3,900	26.5	0.24
	127*	20	0.61	3,900	26.5	0.24
	128	20	0.60	3,900	26.5	0.23
			0.61 avg	3,900 avg	26.5 avg	0.24 avg
OO	129	40	0.61	10,100	26.2	0.23
	130	40	0.62	10,100	26.5	0.23
	131	40	0.60	9,400	26.4	0.23
	132*	40	0.61	9,900	26.5	0.25
			0.61 avg	9,900 avg	26.4 avg	0.24 avg
PP	133	60	0.60	17,400	26.1	0.25
	134*	60	0.62	17,800	26.4	0.27
	135	60	0.61	18,100	26.4	0.28
	136	60	0.61	18,800	26.4	0.27
			0.61 avg	18,000 avg	26.3 avg	0.27 avg
QQ	137	80	0.60	27,700	26.1	0.33
	138	80	0.61	27,600	26.0	0.32
	139	80	0.61	27,200	26.0	0.35
	140*	80	0.61	27,700	26.1	0.34
			0.61 avg	27,600 avg	26.1 avg	0.34 avg
RR	141	100	0.62	45,300	25.4	0.59
	142	100	0.62	43,900	25.5	0.55
	143*	100	0.62	44,000	25.4	0.56
	144	100	0.61	44,000	25.2	0.55
			0.62 avg	44,300 avg	25.4 avg	0.56 avg

* Indicates specimens for metallographic examination.



WELDING ROD CLINIC

J. Imperati and R. F. Pulver, Welding Engineers
The American Brass Company, Waterbury, Conn.

Braze Welding is virtually foolproof for cast iron repairs

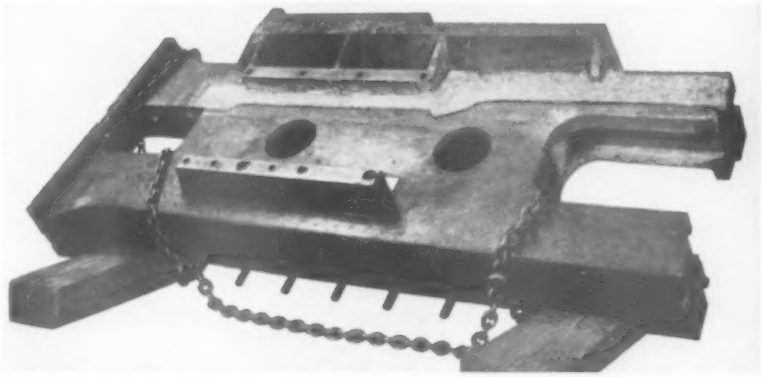
Low temperatures used give strong and enduring welds

The major obstacles to successful repair welding of cast iron are the low strength and poor ductility of cast iron weld metal, and the embrittlement and hardening produced by rapid cooling from welding temperatures.

Oxyacetylene fusion welds with cast iron rods have such very low strength and ductility that they often crack under the stresses imposed during welding and cooling. If they survive these hazards, they sometimes fail when subjected to the service stresses that caused the original failures.

On the other hand, severe embrittlement and hardening of weld and adjacent base metal are easily developed in arc welding because of the steep temperature gradients from weld to base metal. Here also, failure can occur during welding and cooling, or later in service. Usually the weld area is extremely hard and not machinable. It is often necessary to resort to extensive preheating, peening, post-heating, and annealing to avoid these twin evils.

Oxyacetylene braze welding is an excellent solution to the problem for two reasons. With the low temperatures required, there is no rapid cooling from high temperatures and therefore no embrittlement. Excellent ductility and high strength of the weld metal deposited by Tobin Bronze-481, Anaconda-997 (Low Fuming) Bronze, and Nickel Silver-828, permit yielding while the repairs are being made and after they are returned to service, and the danger of failure is practically eliminated.



A 7-foot fracture in this 6-ton press was repair welded in three days—20 hours preparation, 48 hours oxyacetylene welding time, using 400 lb. of Tobin Bronze-481 Welding Rod.

The braze-welding operation itself is virtually foolproof because the molten bronze automatically "tins out" or spreads over the joint surfaces when the correct temperature is reached. Since the base metal is not melted, control of the weld metal is very easy. Braze welding is readily done in all positions.

ADVANTAGES OF BRAZE WELDING WITH ANACONDA RODS ARE:

1. **Economy in welding time** and gas consumption.
2. **Development of low residual stresses** with less distortion and less tendency to crack.
3. **No embrittlement,** and complete machinability of the weld areas.
4. **Minimum delay** in returning the repaired parts to service.

DETAILED INFORMATION AVAILABLE

Detailed suggestions on the methods of chipping grooves, removing oil, positioning the work, and preheating are given in Publication B-13. This 32-page book gives a complete description and full information on Anaconda Welding Rods and discusses procedures for welding with copper and copper alloys in a wide variety of applications.

These are some of the subjects covered: Copper-Alloy Welding Rods in steel sheet metal work, brazing and soldering, resistance welding, surfacing, welding copper alloys to steel, arc-welding of copper and copper alloys.

For information on special problems—or for a copy of Publication B-13—write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

57109

WELDING ROD	APPROX. COMPOSITION, %	APPROX. MELTING POINT	
		Deg. C	Deg. F
Tobin Bronze-481	59 copper, 0.60 tin, 40.40 zinc	885	1625
Anaconda-997 (Low Fuming) Bronze	57.80 copper, 40.27 zinc, 0.95 tin, 0.85 iron, 0.10 silicon and 0.03 manganese	870	1598
Nickel Silver-828	48.58 copper, 41 zinc, 10.25 nickel, 0.15 silicon, 0.02 phosphorus	930	1706

ANACONDA®
WELDING RODS

how's this for *performance?*

15 lbs. of scrap after cutting 156 parts from a 6′ x 10′ plate of ⅜″ steel

Using four torches guided by an electronic tracer, an Airco #48 Duograph automatically flame cut 156 parts from a ⅜″ x 72″ x 120″ steel plate. Of the original 918 pounds of sheet steel, only 15 pounds of scrap remained. Discover the advantages to be gained by using Airco flame-cutting machines for fast, economical production. In addition to the #48 Duograph, Airco flame-cutting machines include the Airco Travograph, Oxygraph, Duograph, Monograph, Camograph, and Radiagraph. Write Airco for complete information and literature.

AT THE FRONTIERS OF welding PROGRESS YOU'LL FIND . . .

AIR REDUCTION PRODUCT

AIR REDUCTION SALES COMPANY

AIRCO®

Offices and dealers in most principal cities

A division of Air Reduction Company, Incorporated
150 East 42nd Street, New York 17, N. Y.

VISIT OUR BOOTH 334 — WELDING SHOW

APRIL 9-11, 1957 • PHILADELPHIA, PA.

On the west coast —
Air Reduction Pacific Company

Internationally —
Airco Company International

In Cuba —
Cuban Air Products Corporation

In Canada —
Air Reduction Canada Limited

Products of the divisions of Air Reduction Company, Incorporated, include: **AIRCO** — industrial gases, welding and cutting equipment, and acetylenic chemicals • **PURECO** — carbon dioxide — gaseous, liquid, solid ("DRY-ICE") • **OHIO** — medical gases and hospital equipment • **NATIONAL CARBIDE** — pipeline acetylene and calcium carbide • **COLTON** — polyvinyl acetate, alcohols, and other synthetic resins.